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USTULINA ZONATA (LEV.) SACC. ON *HEVEA BRASILIENSIS*

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(With Plates III—VIII and 1 Text-figure.)

INTRODUCTION.

Pests and diseases on rubber plantations have caused little anxiety up to date. Scares due to attacks by *Fomes lignosus* (Klotzsch) and White ants (*Termes gestroi*) were prevalent before 1908, but in the general management of Malayan plantations pests and diseases have been considered a minor detail. There are certain estates where preventive measures had to be undertaken because of specific "White ant" or "Fomes" attacks, but these areas are strictly localised. Up to date, no general scheme for combating pests and diseases on rubber plantations could be put forward, for the trees have been extraordinarily free from insect and fungus troubles. Investigations carried out over the last two years indicate that more attention, especially to fungus diseases, will be necessary in the future. A general scheme of treatment may now be recommended with an assurance that money spent on routine disease work will be amply repaid.

HISTORY OF PESTS AND DISEASES ON THE PLANTATIONS.

The pioneer rubber planters in Malaya mostly obtained their experience on the tea and coffee plantations in Ceylon and the tea plantations of India. The failure of the coffee crop in Ceylon owing to the attacks of *Hemileia vastatrix* left a lasting impression, and in the early days of rubber planting, planters were inclined to believe many exaggerated reports of damage caused by various agencies. The root disease caused by *Fomes lignosus* (Klotzsch) was at first regarded as a potential exterminator of young rubber; about the same time the F. M. S. Government offered a $5000 reward for the best cure for "White ant" attacks.

This money was never awarded. Experience taught that "Fomes" attacks, even in the worst affected places where it may cause heavy losses, could be treated, and that attacks by White ants created little material difference in the long run on the majority of plantations. After these scares, a period of indifference to rubber pests and diseases set in until 1912, when the rapidity of spread of "Pink disease" throughout the peninsula stimulated enquiry into the necessity for vigorous treatment. The work of Rant (7) and Brooks and Sharples (2) proved the incidence of the disease and the probable causes of spread, and vigorous preventive measures based upon the work mentioned showed that "Pink disease" could be controlled by concerted effort. Since this time, a large number of plantations have passed the ten years stage and many of the old trees have been killed by fungi attacking the roots. The symptoms have been classed under various headings by Malayan planters i.e. "Wet-feet," "Brown-root disease," "Dry-rot," etc. As a result of work carried out over the last two years these general terms can now be assigned to specific fungi. This contribution deals with the dry collar-rot on old rubber caused by *Ustulina zonata* (Lev.) Sacc.

HISTORY OF DRY COLLAR-ROT.

Brooks (1) in 1915 made the first important contribution to our knowledge on the subject of *U. zonata* as a fungus causing a root disease of plantation rubber. Previous to this, Massee (3) in 1910 published photographs and a description of a fungus, *Eutypa caulivora* (Mass.) growing on a dead tree of *Hevea brasiliensis*, taken from the Singapore Botanic Garden by Mr H. N. Ridley. The photograph of the diseased wood shows the typical symptoms of a tree attacked by *Ustulina zonata*. It is probable this fungus was responsible for the death of the tree, *E. caulivora* growing as a saprophyte on the dead tissue. Numerous saprophytic fungi are always to be found on trees killed by *U. zonata* which are in an advanced state of decay. Petch (4) in 1910 records a case of *U. zonata* growing on an old *Hevea* which had died of root disease, and states that "apparently the disease was caused by this fungus, though the evidence was rather doubtful." Later in 1914 he says (5) "This fungus is a common cause of root disease (*i.e.* of Tea) in Ceylon, though not on Hevea." He records several cases of *U. zonata* on *Hevea brasiliensis* in fields where the trees have been planted among tea which has subsequently been allowed to die out. In 1916 Reeves (8), the Mycologist to the Rubber Growers' Association in Ceylon, published some observations on *U. zonata* with reference to rubber trees, and found the disease common in Ceylon.

There is, as yet, no report of this fungus being found on rubber in Java or in Sumatra.

Brooks obtained the fructifications and as a result of his observations established *U. zonata* as the cause of a collar-rot on *H. brasiliensis*. An account of his observations in Malaya up to the end of 1914 is given (1) when he left for England. At the beginning of 1915 specimens were obtained which necessitated a more complete investigation. This work was carried on through 1915–1916 and various side issues are still under consideration. A general account (10) on economic lines was published in 1916; the following article includes all observations made since 1914 up to the present date.

Petch (5) records several hosts for the fungus: Tea, *Cassia Nodosa*, *Benya ammomilla*, *Casuarina montana*, *Molia Dubra*, *Lafoensia Vandelliana*, *Denis Robusta*, *Citrus Decumana*, *Albizzia Molluccana*, and *Grevillea* sp.

FIELD OBSERVATIONS ON DRY-ROT AND COLLAR-ROT.

In Malaya, the disease is found on old plantations in every part of the peninsula; the fungus is not localised in its distribution as is the case with *Fomes lignosus* (Klotzsch). It attacks old rubber trees in the region of the collar; only in advanced cases does the fungus spread up the stem, and it seldom reaches more than three or four feet above soil level. In one case, however, the fungus has been found travelling from the collar up through the heartwood of the stem into the lower branches, some twelve feet high; externally the tissues appeared healthy except for about two feet above soil level. The fungus travels down through the heartwood of the lateral roots in the same way. The diseased wood in an advanced case is found to be dry and tindery, like touchwood, and running through the diseased tissues conspicuous black lines are to be seen. When the bark is removed, these black lines can be observed in some cases on the outer surface of the wood and, if the lines are followed carefully, it will be seen that they form thin plates of black tissue inside the wood, the edges showing as black lines on the exterior. A longitudinal section taken through the collar of a diseased tree shows these black lines running irregularly in the rotting tissues, often forming circles surrounding dark coloured patches of diseased wood (Pl. III, fig. 1).

There is no external mycelium associated with roots suffering from this disease, though fan-shaped, white patches of a felt-like mycelium may sometimes be observed on the exterior of the wood when the bark is removed. The absence of external strands of mycelium distinguishes

this disease from that caused by *Fomes lignosus*, while the black, rhizomorphic strands between the bark and wood of trees attacked by *Sphaerostilbe repens* serve to distinguish those affected by this fungus. The typical dry-rot in the collar caused by *Ustulina zonata* cannot be mistaken, the wood in advanced cases falling to pieces under the pressure of the fingers.

This root disease is common on most of the older plantations in the F. M. S. though its presence is unsuspected. The fungus works slowly and insidiously, the crown of leaves becoming thin as it progresses in the collar. The diseased tissue is usually confined to one side of the collar, and from this side latex cannot be obtained. The opposite side may give a good yield and tapping is continued till the amount of latex obtained begins to diminish. When this stage is reached the tree soon dies and has to be taken out.

The dry collar-rot has been found occasionally on trees 5–8 years old, but it is only typically developed on trees over 10 years of age. A large number of magnificent trees in the older properties have been killed by this fungus. Cases are quoted later where large areas have been rendered useless owing to attacks by *Ustulina zonata* and other root fungi.

Fructifications are found on diseased roots, usually near soil level. They are closely adpressed to the stem; when young the flat plate-like fructifications are soft, rather leathery, whitish in colour and greenish-white at the edges. Later they darken and become brittle and closely resemble exuded patches of coagulated latex attached to the stem, which have blackened owing to exposure and oxidation. In this condition they are easily overlooked. When the fructifications develop near ground level, they are often difficult to detect as they become splashed with mud after a shower of rain.

OBSERVATIONS IN FIELD ON RELATION BETWEEN SHOT-HOLE BORER (*XYLEBORUS PARVULUS*) AND *USTULINA ZONATA*.

In the report of the Director of Agriculture, F. M. S. for 1914, H. C. Pratt, Government Entomologist, writes:

"*Xyleborus parvulus*. This beetle was first noticed in this country as attacking rubber in 1909. It occurred only in one district. The instance was undoubtedly due to the pollarding of a large number of trees. Many of these pollarded trees were attacked, and in a few cases adjacent trees which had not been pollarded were bored. Since that time this district has always lost a few trees each year from what would appear to be the attacks of this insect. During 1914 there was a remarkable increase in

the number of cases reported to the Department of Agriculture, and there has been a corresponding increase in the districts in which it now occurs. It is instructive to find that all estates which are affected were either thinning-out the number of trees to the acre or had just finished this work."

The practice of planting trees to the number of 150–200 an acre on rubber plantations renders necessary the cutting out of large numbers when they reach the age of 6–7 years. During the thinning, attacks by boring beetles on the permanent trees become prevalent. Early in 1915 a living specimen of a rubber tree attacked by borers was obtained. This specimen (*A*) showed the insects active along one side of the stem extending from three feet above ground level to a height of twelve feet. The roots were healthy. Sections through the attacked parts showed that the borers were penetrating through rotten wood. Running irregularly through the rotten wood were black lines very similar to those observed in a typical case of dry collar-rot (Pl. III, figs. 3 and 4).

Immature fructifications of an *Ustulina* sp. were obtained on the surface of the attacked parts. On a neighbouring dead tree (*B*) attacked by borers, typical specimens of *Ustulina* fructifications bearing a conidial layer were observed in various stages of growth upon the bark; in close proximity numerous saprophytic fungi were growing. Sections of this tree showed more advanced symptoms than those found in specimen (*A*); these symptoms were identical with those found in the dry collar-rot of *Hevea brasiliensis* caused by *U. zonata*. A fungus was isolated from the affected wood in specimen (*A*) which proved to be practically identical with cultures established from typical dry collar-rot trees.

It would appear from the above that there is some connection between *U. zonata* and attacks by boring beetles. Much evidence to support a close connection can be advanced. Several estates in the F. M. S. were troubled during 1915 with leaf fires. Owing to a heavy wintering the leaves formed a layer several inches thick on the ground, and when dry the leaves are easily fired. In the areas through which the fires passed the bark of the trees was scorched and boring beetles quickly entered, though the latex streamed freely. On one estate, every tree in a nine-acre block of rubber, nine years old, had to be removed; four other estates encountered the same trouble on a smaller scale. In every tree entered by the borers the same symptoms described for specimen (*A*) were observed; the insects were penetrating actively a rotting portion of the wood through which black lines ran irregularly. Some time was spent trying to find scorched trees attacked by the fungus only. Specimens

were obtained showing but five or six boreholes and the fungus working actively in the wood, but no case was found where borers were entirely absent. In the great majority of the trees, the association of insect and fungus was very pronounced. The fungus was carefully isolated from several of these trees and was identical with the cultures obtained from specimen (*A*).

Further supporting evidence for the connection between *Ustulina zonata* and attacks by boring beetles was obtained in an experiment described (9). In this experiment the bark of twenty-four rubber trees was scraped in order to see whether this treatment rendered them more liable to insect and fungus attacks. The laticiferous system was not injured in any way, the scraping being performed to compare heavy scraping—the cork-cambium being removed—and light scraping—the cork-cambium being left intact as far as possible. Five trees of the total treated were quickly attacked, three by borers. Two of the three trees attacked by borers showed traces of *Ustulina zonata* in the bark five weeks after the insects entered. In one tree, the fungus made beautiful progress and daily observations were made. An interesting point is that the borers disappeared after the first fortnight and the rate of growth of the fungus in the wood of the stem and collar could be directly compared. Pl. IV, fig. 5 is a photograph taken four days after the trees were scraped and shows the latex streaming down the trunk from the holes made by the beetles. Fig. 6 shows the surface of the wood exposed with the typical black lines formed by the fungus. Pl. VIII, fig. 21 shows a section through the diseased part six months after the scraping, and a comparison with Pl. VII, fig. 19, which represents a typical artificial inoculation at the collar about six months old, shows that the rate of growth of the fungus in the stem and collar is almost the same.

This experiment (9) indicates that the important protective layer in rubber trees is the outer layer of corky cells, and if this layer is injured, they are liable to attack by boring beetles. The laticiferous layer affords comparatively little protection against borer attacks beyond preventing the entry of the first few insects. The first comers trying to enter were trapped in the streaming latex, but later arrivals succeeded in entering through places prepared by their predecessors. On the estates troubled with leaf fires the scorching of the bark did not interfere with the presumed protective function of the laticiferous system of the trees, for the latex streamed freely from the holes made by the borers.

The above evidence affords a convincing explanation of the prevalence of borer attacks at the time of thinning out. When a tree is felled

its branches come in contact with and bruise the branches and trunks of neighbouring trees, wounding the outer corky layers. Through these places boring beetles enter and the fungus *U. zonata* may be taken in by, or quickly follows the insects. The fungus penetrates the wood quickly, for the insects bore to every part of the tree carrying small pieces of diseased tissue, so setting up innumerable centres of infection. The fructifications form on the surface of the diseased parts, and spores from these are blown about the plantation. The rubber logs and stumps lying about the thinned-out areas form suitable growing places, as does any rotting soft-wood timber, and thus the fungus obtains suitable conditions for perpetuation and spread.

When a tree attacked by borers is examined, the typical symptoms caused by *U. zonata* can nearly always be demonstrated. The association is probably due to the fact that a tree penetrated by borers is very liable to attack from common wound-fungi. *Ustulina zonata* is a wound parasite on *Hevea brasiliensis*, and is also one of the commonest causes of rotting in soft-wood timber in the plantations. Its prevalence on the plantations in rotting timber and stumps increases its chances of attacking rubber trees whenever a suitable opportunity occurs. The fungus often gains an entry through wounds caused by the breaking of large branches. In these cases, there is always a copious exudation of latex for a lengthy period as fresh areas of healthy bark are attacked during the progress of the fungus. It passes much more quickly through the wood than the bark. It would appear that *Ustulina zonata* does not easily attack rubber trees unless an exposed wood surface, or a convenient path to a wood surface, as in trees penetrated by borers, is provided.

Fructifications are found on all parts of the stem and branches where the fungus is working in the tissues. "Stag's head" in rubber trees is a well-known phenomenon and is usually attributed to *Diplodia* sp., the cause of "Die-back." On two occasions the fruit-bodies of *U. zonata* have been observed growing on these dead branches taken from the topmost parts of the tree. When the fungus gains an entry through wounds caused by the breaking of large branches, a large quantity of fruit is usually produced about the place of entry; the later blackened stage of the fructifications are often masked by a copious exudation of latex from the diseased portions.

It is possible that borers may directly transfer spores to the trees they enter. Insects such as White ants, Red ants, etc. walking over the flat plate-like fruit-bodies when the latter are producing spores would carry away numerous conidia or ascopores attached to their appendages. Fructifi-

cations in the conidial stage have been found showing traces of insect markings; whether the latter were feeding on the spores is doubtful, but it was obvious they had spent some time upon the surface, judging from the intricate tracings.

Several cases of old trees hollowed by White ants and attacked by the fungus have been found (Pl.IV,fig. 8). These trees were all twelve years old; some had been successfully treated with the White-ant pumping machine at the age of eight years. The number of trees found attacked by White ants and *U. zonata* is comparatively small when compared with those attacked by boring beetles and *U. zonata,* or the number of old trees suffering only from the fungus attack. In a consideration of treatment and spread of the fungus, the White ant question appears to be of minor importance.

DESCRIPTION OF THE FUNGUS.

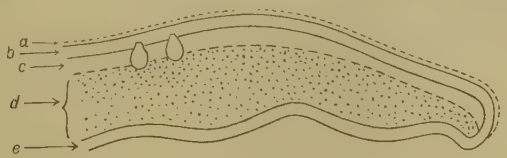
The development of the fruit-bodies of *U. zonata* has been carefully studied in the laboratory. Brooks' (1) description of Malayan specimens is incomplete because up to the time of his departure he had not seen the fructifications in the early stages. It may be stated here that the Malayan specimens correspond in every respect to the description given by Petch (4) for those of Ceylon.

The common fructification commences as a small yellowish-white plate closely adpressed to the bark. The plate increases in size and the surface darkens to a greenish-grey colour. This change in colour is due to the formation of a thick conidial layer. In the Laboratory this stage persists for about a week, and during this period the stroma is soft and easily cut. Owing to the disappearance of the conidial layer, the stroma becomes darker; as it ages it takes on a leathery consistency and ultimately becomes quite brittle and black. Typical young specimens in the field show a well-defined zoning on the surface (Pl.IV,fig. 7 and Pl.V,fig. 9) but those developed in the Laboratory did not show a conspicuously zoned surface. When fully developed the plate-like fructifications are several inches in diameter. A number of these plates may fuse together; large plates formed by fusion of smaller ones have been found covering an area of the stem three feet in length and nine inches broad.

When the flat plate-like fructifications are broken across, the tissues are found to be arranged in distinct layers. The accompanying diagram (after Brooks) illustrates the different layers.

On the upper surface (*a*) represents the remains of the conidial layer. Brooks did not observe the conidial layer in the specimens obtained by

him in Malaya, though it appears a constant feature. It is very transitory as observed in the Laboratory; 4–5 days is the actual time between its appearance and the dispersal of the spores. (*b*) is the upper black zone, composed of compact tissue very similar to that composing the black lines, as seen in a diseased collar. (*c*) is a white loosely compacted zone in which the globular perithecia are formed. (*d*) is a broader band, grey in colour and leathery in consistency. (*e*) is the black zone on the under surface, which is continuous at the margins with the black zone towards the upper surface.



The globose perithecia communicate with the exterior by very narrow channels. The first formed elements of the perithecia can be recognised in suitably stained sections very early in the development of the fructification, long before the production of conidia. These elements stain more deeply with protoplasmic stains than surrounding ones and appear as small circular patches of spirally running hyphae.

In the early stages of development, the black zone is not present in the fructification. Whilst the stroma is still soft and yellowish, the walls of patches of cells of the loosely compacted layer, irregularly distributed, but at the same depth, become impregnated with carbonaceous material. Later, the walls of the cells of the loosely compacted layer intervening between the black patches become impregnated with similar material, their cell contents darken, and a continuous black, brittle zone is formed. It is a very characteristic zone, and can be used as a rough diagnostic feature when studying the variable forms of fructifications produced by this fungus. This zone is always present in the "Xylaria" forms of the fungus; many true *Xylarias* are found on rubber trees killed by *U. zonata*, but these do not show the black carbonaceous zone to which the fructification of *U. zonata* owes its brittleness. The greenish-grey conidial layer is formed about the time the black zone is completed, while the fructification is still rather soft and leathery. In many cases observed, the conidial layer is restricted to the younger, growing edges of the fructification, while the older parts in the middle are showing the ostioles of the perithecia. The hyaline conidia are abstricted abundantly from the

apices of hyaline hyphae compacted to form a smooth surface. They measure four microns by two.

The perithecial openings can be observed as minute black spots almost immediately after the disappearance of the conidial layer. By this time the black zone is continuous, and the spore chambers are developed just below this zone in the more loosely compacted tissue. The asci are numerous, with paraphyses. The ascospores, when first delimited from the remainder of the protoplasm in the ascus, are hyaline, with no special contents. Later, they darken, become almost black, with two or three oil drops. They are slightly curved, inequilateral and lie to end in the ascus. The ascospores are 28–32 microns by 7–10 microns. They exude through the openings of the perithecia under moist conditions, looking like small drops of ink. When the amount of moisture fails, the exuded spore masses spread out over the surface, resembling black patches of dust surrounding the perithecial openings. Only on one occasion did the ascospores germinate readily; these were obtained immediately after extrusion from a fructification developed in the laboratory. Placed in potato mush agar in damp chambers they germinated in twenty-four hours, several germ tubes being put out along the side of the spore, none from the ends. The tubes grow vigorously and branch profusely.

The conidia germinate more easily, but do not produce a copious mycelium on potato mush agar in damp chambers. Conidia placed directly on slants, however, produce just as vigorous a mycelium as is formed from sowings of ascospores. Cultures are not easy to obtain from spores developed in the field, though the fungus can nearly always be obtained in pure culture from the black lines formed in the diseased tissue.

There is as much variety in the form of the specimens from Malaya as in those from Ceylon described by Petch. There is a solitary stalked form (Pl. V, fig. 11), the conidial layer being produced only on the top and continued a short distance down the sides. In some cases, these stalked forms may be aggregated to form a compact plate, the heads of the stalks becoming hexagonal in shape owing to mutual pressure. This approximates to the typical Kretschmaria form, the common *Kretschmaria coenopus* (Fr.) closely resembling this form of *U. zonata*, but the ascospores of the latter are much larger. There is another form which has not yet been found to produce spores; this closely resembles a foliose lichen (Pl. VI, fig. 14). Pl. V, fig. 10 shows a photograph of a fructification with the lichenoid type at the edges, gradually passing into the plate-like form with hexagonal heads; the commoner flat plate-like form was growing up from beneath

the stalked form. In the photograph the growing over the stalked form masks the presence of the commoner form.

CULTURE EXPERIMENTS.

The *Ustulina* fructifications found on specimen (*B*) differed from those previously found in the F. M. S., for a typical conidial layer was formed as in specimens described from other countries. A further difference was observed, for the fungus attacking the wood in specimen (*A*) was isolated and the pure cultures lacked the typical zoning (Pl. VI, fig. 17 A) of those obtained by the isolation of the fungus from the rotting tissues at the collar. Again the bored trees showing this fungus were killed very quickly while the collar-rot proceeds very slowly.

Owing to these differences, critical cultural experiments were undertaken to decide whether there were two distinct species of *Ustulina* capable of attacking rubber, *Ustulina zonata* causing a collar-rot and another species distinct from, but closely related to *Ustulina zonata*, causing a stem-rot in conjunction with boring beetles.

TYPICAL CULTURES OBTAINED FROM COLLAR-ROT.

Pure cultures were first established after numerous failures by taking a small portion of one of the black lines from the collar under sterile conditions and placing it on a block of sterilised *Hevea* wood in a culture tube. Several days after sowing a greyish mycelium began to grow and spread out slowly over the surface of the block, remaining closely adpressed. As the growth continues, the mycelium turns black, forming a thin crust. If the cultures are allowed to develop for several weeks and the blocks taken out and cut open, black lines similar to those formed in the tissues in cases of collar-rot are seen in the middle (Pl. VIII, fig. 23).

Small pieces of the black crust from the wood blocks were taken and used to inoculate flask cultures of potato mush agar. A white flocculent mycelium first developed; after three or four weeks the surface of the jelly was covered with a black crust similar to that developed over the wood blocks. The crusts in these cultures showed a typical zonation, dark and light zones being formed owing to a thicker aggregation of hyphae at one part than another.

CULTURES OBTAINED FROM STEM OF SPECIMEN (*A*).

A description of symptoms shown by this specimen is given above. The trunk of the tree was sent into the Laboratory and the affected portion cut into sections. The boundary between diseased and healthy

wood was well marked by a diffuse brown discoloration, and after twenty-four hours in the Laboratory, a copious white mycelium appeared at this junction. Pieces of this mycelium used to inoculate flask cultures of potato agar gave rise to cultures which, except for the absence of zoning, corresponded to those obtained from the collar-rot caused by *Ustulina zonata*.

Other cultures were started by placing small portions of the black lines developed in the rotten portions of the wood in sterile damp chambers. In two days hyphae began to grow out; after four days the small pieces of diseased tissue with the attached mycelium were taken and placed in flask cultures; similar non-zoned cultures to the ones described were ultimately obtained.

The boreholes made by the insects through the rotten wood were filled with fungus mycelium. Small portions were taken to inoculate other flasks and again non-zoned cultures resulted.

The non-zoned cultures are characterised by a peculiar folding of the crust which forms on the surface, due to unequal growth in different directions. This folding is seen especially well when the culture medium is rather soft; when hard the folds radiate out from the centre in a more or less even manner.

CULTURES FROM SCORCHED TREES.

Stems of the trees attacked by borers, from estates which were troubled with leaf fires, were taken to the Laboratory and the fungus isolated from them. Specimens from two estates were treated and typical non-zoned cultures were obtained starting from small pieces of the black lines.

CULTURES FROM CONIDIA AND ASCOSPORES.

From another estate which suffered similar damage owing to a leaf fire a rubber log was obtained carrying a large fructification twelve inches long and four inches broad on the stem. Over the greater portion of the surface the smooth conidial layer was present. After two days in the Laboratory the ascospores began to be extruded from the perithecia over about one square inch of the stroma. Cultures were obtained from the ascospores by setting a few of these in flask cultures. Non-zoned cultures resulted.

Cultures are difficult to start from conidia. Numerous foreign spores fall on the flat fructifications, and these develop more quickly in cultures than those of *Ustulina zonata*, with the result that the latter is crowded

out. Cultures were successfully established from conidia by carefully rubbing away the upper layers of old spores with a sterile needle, using young spores from beneath to inoculate test-tubes of potato-mush agar. These cultures when transferred to flasks showed an interesting transition, indicating that the zoning of the cultures is variable, depending largely on external conditions. Pl. VI, figs. 15–17 show a series of photographs of flask cultures originating from the conidia. Figs. 15 A and 15 B show a culture zoned on both surfaces. Fig. 16 A shows the zoning on the upper surface, but the photograph of the under surface 16 B shows that the zoning does not extend through the substance of the culture as in a typically zoned one. Fig. 17 B shows the under surface of a non-zoned culture, exactly similar to the under-surface shown in Fig. 16 B while Fig. 17 A shows the typical under-surface of a zoned culture.

The action of the light on the zoning was tested by inoculating flask cultures with small pieces of the crust taken from a zoned one. These cultures were allowed to grow for a few days till the zoning became apparent in all of them. At this stage some of those showing two or three rings were placed in the dark, the other allowed to stand in diffuse light in the Laboratory. The latter developed into zoned cultures. In those placed in the dark the zoning stops immediately. The zoning of the fungus in pure culture is not constant, but can be varied by changing the conditions under which it is growing.

Fructifications were not obtained in pure culture till the end of 1916. It was then found that if sufficient water is placed in the culture tube to cover the cotton wool and partially immerse the wood block, the fungus immediately commences to produce growths resembling fructifications. The top end of the wood block must project slightly above the surface of the water and be kept comparatively dry in order to provide a suitable place for inoculation. The fungus quickly strikes away, and growing down the block through the water produces thin, black plate-like structures resembling the plate-like fructification found in nature. The fungus grows through the cotton wool and in one case produced the "Kretschmaria" form on the lower end of the wood block. Two or three weeks after the "Kretschmaria" form was noticed, small protuberances appeared on the upper end block which finally took on the "Xylarial" form; these were black stalked with a small greenish-grey head. The latter colour was due to the production of the typical conidial layer. Slants were started from these conidia, and typical cultures obtained. Thus the whole cycle of the life history has been obtained with the exception of the ascospore stage.

Fertile fructifications have not yet been obtained in agar cultures. Small rhizomorphic-like strands which attain a height of $\frac{1}{4}''$ above the surface of the culture are often found (Pl. VII, fig. 18). These strands resemble the individual components of the lichenoid form of the fungus. They grow about in the culture medium in a very irregular manner, and are doubtless comparable with the black lines running through the rotten wood of plants affected with *U. zonata*.

These experiments prove that *Ustulina zonata* is the fungus largely responsible for the death of trees attacked by borers. Attacks by boring beetles would not prove serious if other agencies were not concerned. The connection between the insects and this fungus, which is the cause of one of the most serious diseases on old rubber we shall have to contend with in Malaya, renders the question of the control of collar-rot a difficult one. It is obvious, however, that strict attention must be given to all trees, stumps or logs in which borers are working.

FUNGUS IN THE WOOD.

The progress of the fungus in the tissues is well shown by Fig. 19, which shows an artificial inoculation at the collar. The fungus advances from the point of inoculation into the wood and spreads more quickly in this than in the bark. The wood assumes a brown colour as the fungus advances, this discoloration extending fairly evenly in the vertical and lateral directions. Attention may be called to the apparent zoning shown by the discoloured tissues.

The brown wood is permeated with thin hyaline hyphae largely confined to the medullary rays and fibres of the wood. The vessels are comparatively little affected; only when the black lines cross the vertical path of the vessels are hyphae noticeable in them.

The fungus causes a drying of the affected tissues; the wood becomes crumbly and falls apart under the pressure of the fingers in advanced cases. The black lines of fungus tissue appear as the affected wood dries. These lines are formed by the aggregation and massing of hyaline hyphae; this aggregation always commences in the medullary rays (Pl. VII, fig. 20). Later, tracts of connecting cells between the rays become filled with similar tissue, and a continuous line is formed. Carbonaceous material is deposited in the cells after aggregation, and as time passes it is often difficult to detect their origin. The elements bordering the lines are crowded with hyaline hyphae.

The slow progress of the fungus in the root system is connected with its method of penetrating the tissues. The vessels are the routes along

which quick travelling fungi, such as *Diplodia cacaoicola* (P. Henn) and *Corticium salmonicolor* (Zimm.) proceed, and the hyphae of these fungi are always specially noticeable in the vessels. *C. salmonicolor* is noteworthy in this respect, for as it passes along the vessels the living cells bordering them produce tyloses (2) in an attempt to stop the progress of the fungus. The vessels in wood attacked by *U. zonata* seldom show these ingrowths; Brooks (1) also calls attention to this absence of tyloses.

BLACK LINES IN ROTTING WOOD.

The tendency for fungi to produce black lines similar to those described for *U. zonata* is a noteworthy feature in the tropics. All rotting soft-wood logs on the plantations show these lines when the wood is cut. These lines are an important diagnostic feature to the planter, and more certain knowledge of the fungi forming lines in rotting soft wood on the plantations is desirable. A special investigation is under weigh, results of which are not yet to hand.

INOCULATION EXPERIMENTS.

The inoculations described by Brooks (1) indicate that the fungus will easily enter the collar of a rubber tree through wounds, but cannot enter a healthy unwounded tree. On very young unwounded seedlings, he obtained successful artificial inoculations, but similar trials on woody plants were unsuccessful.

Usually a fungus is limited in its infective capacity to either the aerial or underground portions of a plant, i.e. a fungus causing a root-rot will not attack the stems and branches of a particular host, and *vice versa*. *A priori* considerations lead to the conclusion that a wound parasite on roots might easily attack branches through wounds, but experimental evidence was desirable. The inoculation experiments to be described settle this question, and also bring evidence to support the result arrived at by culture experiments and field observations which proved that *U. zonata* is the organism causing the rotting of the tissues in rubber stems and branches attacked by borers.

Roots were inoculated with the fungus (*U, s*) isolated from the stem and branches, and branches were inoculated with the fungus (*U, r*) isolated from the roots.

Expt. 1. Eight seedlings were inoculated on 17. vi. 15. These plants were six months old, and had developed a woody stem at and for about eight inches above the collar. Four were inoculated with (*U, r*) four with (*U, s*). The inoculations were made by placing small pieces of rubber

wood on which the fungus was growing in pure culture in slight cuts made with a sterile knife, either in the collar or woody parts of the stem. Control plants were kept; these were treated in the same way, but small pieces of newly sterilised wood were placed in the cuts. The results are placed in tabular form below.

Date examined	*U* (*r*) at collar		*U* (*r*) in in stem		*U* (*s*) at collar		*U* (*s*) in in stem	
No.	1*	2*	3*	4*	5*	6*	7*	8*
24. vii. 15	...	+	...	...	...	...	...	...
27. vii. 15	...	...	...	...	...	...	+	...
29. vii. 15	...	...	+	...	...	...	...	...
11. viii. 15	+	...	...	...	...	...	...	...
5. x. 15	...	...	...	+	+	...	...	...
6. x. 15	...	...	...	...	...	−	...	+

* Nos. 1, 2, 3 and 7 were dead on the date of examination. The death symptoms were typical, the leaves suddenly wilting. When the plants were cut open at the point of inoculation the progress of the fungus for one or two inches above and below this place was clear, and black lines were forming in the diseased tissues from the wounded places. No. 5 gave a similar result, but the plant was examined before the leaves wilted. Nos. 4 and 8 showed the fungus progressing in the tissues on the date of examination, while No. 6 completely recovered. Cuts made in control plants all healed quickly.

Expt. 2. In this experiment, similar inoculations were carried out on five year old, untapped trees growing in an area clear of all rotting timber. Eighteen trees were inoculated, nine with *U* (*r*), nine with *U* (*s*). Six each of *U* (*r*) and *U* (*s*) were made at the collar, the bark being lifted with a sterile knife, and a small piece of culture wood inserted. Six inoculations were made in the branches, three with *U* (*r*), three with *U* (*s*). These were made by cutting deeply into the cortex and inserting similar pieces of culture wood as those used in the collar inoculations. Inoculations made: 22. vi. 15, and examined: 1. ii. 16.

Tree No.	*U* (*r*) at collar	Tree No.	*U* (*r*) in branches	Tree No.	*U* (*s*) in branches	Tree No.	*U* (*s*) at collar	Remarks
1	+	7	+	10	+	13	+	Lost may be taken
2	+	8	+	11	−	14	−	as unsuccessful
3	+	9	+	12	+	15	+	
4	+	...	...	...	...	16	Lost	
5	−	...	...	...	...	17	+	
6	Lost	...	...	...	...	18	Lost	

The tabulated results of Experiment 2 show that twelve out of eighteen inoculations were successful. The branch inoculations were uniformly good, both with *U* (*r*) and *U* (*s*). Seven out of twelve root inoculations were successful. Considering the difficulties attached to root inoculations, this result is most conclusive.

The rapidity of the healing of the wounds in the control plants is noteworthy. In Experiment 1, observations were continued for some time comparing Nos. 4 and 8, in which cases the fungus penetrated slowly about the wounded part, and the control plants where sterilised slips of wood were placed in the cuts. Healthy callus healed the wounds in the controls in two months, while the wounds in Nos. 4 and 8 showed no signs of healing after three and four months. Compared with No. 6, which recovered completely, the cuts in the controls healed much more rapidly. The control plants in both experiments continued to flourish.

These inoculation experiments confirm the conclusions arrived at by field observations and cultural experiments. The capacity of *Ustulina zonata* to attack either the roots or aerial parts of rubber trees through wounds can no longer be doubted. The fungus makes very appreciable progress in the tissues in six months' time as is indicated by the photographs shown, Pl. VII, fig. 19 and Pl. VIII, fig. 21. The common occurrence of this fungus on the plantations renders it a matter of extreme import that vigorous measures should be undertaken to prevent its spread. The measures to be adopted will now be considered.

SOURCES AND MANNER OF INFECTION.

Petch(4) states that *Ustulina zonata* is the cause of the commonest root disease of Tea in Ceylon, and that its prevalence is due to the practice of growing *Grevillea* among tea and cutting it out later for firewood, or when it has grown too big. The same applies when *Albizzia moluccana* is planted through tea, and afterwards felled. The *Grevillea* and *Albizzia* stumps left in the ground are rotted away owing to the action of fungi, and *U. zonata* is the commonest one growing in them. In the same way, this fungus appears to be one of the chief agents causing the rotting of rubber stumps and logs left in the plantations after thinning-out.

On the tea plantations, the fungus enters the *Grevillea* and *Albizzia* stumps and grows down them into the lateral roots. The roots of the tea bushes in contact with these infected laterals are quickly attacked. The same method of spread operates in the rubber plantations after the thinning-out period if the stumps of the cut trees are left in the ground. Lateral roots of infected trees have been traced to old rubber stumps left after thinning, on which the fructifications of the fungus were developing. Further, on the badly affected plantations noted up to date, the stumps of the rubber trees were not removed after thinning-out.

There is, in Malaya, a wide-spread dispersal of the fungus through the

plantations by means of the spores after the thinning-out period. The fungus enters permanent trees attacked by boring beetles and quickly kills them, and the stumps and felled logs form excellent material in which the beetles and fungus may work together. But the fungus alone can enter and grow through any soft-wood timber without the aid of the insects.

All trees attacked by boring beetles should be immediately cut out and destroyed, as they represent one of the worst sources of infection. Strict attention should be given to trees scorched by fire, and if borers attempt to enter, a coating of tar and crude oil (80 per cent.–20 per cent.) should be applied over the scorched surfaces. In the case of scorched trees resulting from leaf fires, the burnt areas are usually situated near ground level, and can be easily treated with the tar mixture. A second coating should quickly follow the first. Scorching of higher branches resulting from burning of piles of timber is not so easily treated, but as far as observation goes, these branches are not often attacked by the insects; in any case they can be cut away from the main stem quite easily.

The cases of leaf fires noted this year—1916—support the observations made in 1915 and given above. One interesting case was noted: an estate was visited four days after the fire and borers were already at work on half a dozen trees not badly scorched; latex was exuding freely from the boreholes.

At the time of thinning-out a tremendous increase of suitable food material for the fungus becomes available. Practically all stumps and felled logs of rubber if left lying about the plantation for any length of time show signs of *Ustulina zonata*. The fructifications develop on the surface of these logs and stumps, and for a short period corresponding to the weekly one observed in the Laboratory, a copious supply of spores (conidia) is produced and blown about the plantation by the wind. Later, the ascospores ripen, and these are distributed amongst the trees by various agencies.

The spores come to rest in wounds in the collar and lateral roots of the permanent trees and under suitable conditions germinate. The fungus develops slowly, and several years later when the trees are passing the ten years' limit, some begin to show a thin crown of leaves. If the collar is now cut open, the characteristic dry-rot will be found.

The fungus is also found on rotting jungle timber and on old jungle stumps left in the plantations after burning-off. It is not so common in the early years as it is during or after the thinning-out period, though

many cases have been found recently of roots of four year old trees permeated and killed by this fungus. The jungle stumps and timber represent one of the sources from which the fungus commences, for fructifications have been obtained from old jungle stumps (Pl. III, fig. 2) and characteristic symptoms have been observed in lateral roots of jungle stumps exposed in areas treated for *Fomes lignosus*.

It is probable that healthy jungle trees are attacked by this fungus, and spores may be blown from the jungle into the plantations. It is impossible to take the measures to prevent the spread of the fungus from this source. On a clean estate, there is little danger to be anticipated, and in the general scheme of treatment it may be considered negligible.

TREATMENT.

This consideration of the sources and manner of infection indicates that present day plantations may be divided into three groups. The treatment accorded to each group varies with age. The groups are as follows:

(*A*) *Young plantations not thinned out.*

(*B*) *Plantations thinning-out with trees not ten years old.*

(*C*) *Plantations with trees over ten years of age.* –

(*a*) Control measures against the collar-rot caused by *Ustulina zonata* may be initiated by enforcing strict sanitation methods from the time of planting up. The clearing of the ground of rotting timber and the treatment of jungle stumps is the first and immediate measure to be undertaken. This will largely prevent trouble from *White ants* and *Fomes lignosus*, as well as minimising that likely to ensue from attacks of *Ustulina zonata*. Special attention should be paid to the eradication of the lateral roots of jungle stumps to prevent contact infection from both *Fomes lignosus* and *Ustulina zonata*. This can be secured best by following up the laterals from the stumps to a depth of two feet below the surface. At this point they should be cut through and separated from the parent stump. Clearing timber and eradicating stumps or lateral roots is costly, and the difficulty of the undertaking fully appreciated. Though many of the larger stumps will have to be left standing, yet it is possible to clear any estate to such an extent that trouble from root diseases may be reduced to a negligible quantity.

On estates badly affected with *Fomes semitostus*, the elimination of stumps and timber, as far as is practicable, has been fully recompensed. General treatment on these lines could not be advised previously, for large numbers of estates are free from "Fomes" troubles, but few will

escape attacks by *Ustulina zonata*. This fungus appears likely to cause damage on most old properties.

(*b*) *Plantations thinning-out with trees not yet ten years old.*

Estates about to thin out from which no jungle stumps have been removed or timber cleared, should attempt to follow the advice given under (*a*). On all estates the method of thinning-out should follow the same lines as treatment advised for clearing land at the beginning. One tree should be cut, and the stump, lateral roots and logs removed and destroyed immediately. A sharp watch should be kept over the thinned area for signs of borer attacks on standing trees and those attacked should be cut out and destroyed quickly. This treatment prevents the multiplication of boring beetles by destroying their breeding grounds.

PERIOD AFTER TREES ARE TEN YEARS OLD.

On most old plantations in Malaya, this disease will be found to be responsible for the death of numerous trees. In a previous publication (10) the writer stated that it might be possible to treat old trees attacked at the collar by cutting out the diseased tissues and running a pillar of concrete up the middle. Since then, this method has been tried, but from the planters' point of view is unsatisfactory because of the expense. Therefore, if diseased trees are found in an advanced state of decay, they should be cut out immediately, care being taken to remove all diseased laterals to prevent contact infection. The greatest damage on old plantations arises from infection of roots of healthy trees by contact with diseased laterals of neighbouring trees; the recognition of this fact must not lead to a minimisation of the dangers of spore infection.

Fructifications are common on the surface of the diseased tissues at the collar. They develop quickly, so a constant watch should be kept on attacked trees, if left standing. Two examinations a week would be advisable, and immediately fructifications are observed, a tin of kerosene oil should be obtained and the fruit-body gathered and immersed in the oil. This will help to prevent the spread of the fungus about the plantation by means of wind-borne spores. Wounded lateral roots on trees over six years old showing above the surface of the soil are convenient places of entry for the fungus. Such roots showing black lines below the wounds should be cut off if they can be spared.

Many managers see difficulties in the amount of burning which is required. Burning, however, is carried out successfully all the year round on many estates in the treatment of "Pink Disease," with little damage to the permanent trees.

FUTURE POLICY AND CONCLUSION.

It is an accepted fact that pests and diseases are a constant menace to all plantation industries. The potential dangers to the Rubber Plantations in Malaya are becoming more manifest each year, and the menace is doubly dangerous because of the comparative immunity of the plantations up to date, which has lulled responsible persons into a false sense of security. Many significant facts have been brought to light during the last two years. A few cases of serious attacks of root disease in rubber plantations might be quoted:

(*a*) On one estate, a block of 6–7 acres of sixteen year old rubber was examined—sixty trees to the acre. A casual inspection revealed 120 trees attacked by *U. zonata*. More have since been found.

(*b*) The Government estate behind the offices of the Department of Agriculture at Kuala Lumpur carries about seven acres of fifteen years old trees. A fair number of cases of *U. zonata* were known, but only one small group of six trees was known to be affected with "wet root-rot[1]." To obtain specimens and observe the disease below ground, this group, together with the neighbouring trees, was opened up. It was obvious from the commencement that the subterranean spread was much greater than at first anticipated. Two hundred and twelve trees were opened up, and forty per cent. showed diseased roots (i.e. wet root-rot). The matter was so serious that at the request of the Advisory Committee to the Department of Agriculture, the whole of the seven acres of old rubber had their roots exposed. Over the whole area, in which 700 trees were examined, twenty per cent. showed diseased roots.

(*c*) A third illuminating case was noted some months ago. A wind storm, locally known as "Sumatra," swept over a portion of one estate, and a large number of seventeen year old trees were blown over. Of these prostrate trees, only three showed healthy roots; these were without tap roots. A few of the fallen trees had been treated previously for *U. zonata*, but by far the great majority which were not suspected to be suffering from root disease, had *U. zonata* attacking the roots. A few cases of branch infections with *U. zonata* and a few roots with wet root-rot, were also found. When the place is cleared, huge gaps must be left in the wind swept area. The manager is quite certain that any other portion of the old rubber subjected to a similar storm would show a larger number of unsuspected cases of root disease. This, and the case quoted immediately above, shows the insidious spread of these root fungi on old

[1] Belgrave, W. N. C. "A Root disease of Plantation Rubber in Malaya." *Agr. Bull. Fed. Malay States*, Vol. iv. No. 11. Aug. 1916.

rubber, and it is impossible to urge too strongly the necessity for immediate and strenuous measures to keep them under control.

A further complication arises: during the last six months, serious outbreaks of different manifestations of so-called Bark Canker have been found in widely separated districts in Malaya. The important point in combating diseases of renewing bark is that the trees should be assured proper ventilation. The more light and air penetrating to the trees, the less chance of epidemics of Bark Canker. If Bark Canker becomes general in Malaya, thinning-out will have to be undertaken to the irreducible minimum number of trees per acre commensurate with profitable working. When estates are forced to this position, the menace of a bad attack of root disease is obvious.

A critical period approaches for the plantation rubber industry in Malaya. No immediate danger promises though the menace of disease becomes more prominent every year. Fungus diseases will, in the long run, provide the limiting factor, preventing the expansion and hindering the progress of the industry. The logical conclusion drawn from facts as they present themselves is that if preventive measures are not immediately adopted, fungus diseases may prove the ultimate ruin of an industry, which with careful foresight and administration, should smother all competitors for decades.

The future policy to be adopted in Malayan rubber plantations must be one of two: either

(*a*) An attempt to keep the present plantations healthy as long as possible, or

(*b*) A re-planting scheme at an age between 20–30 years.

The profits gained by a rubber plantation depend upon the average yield of dry rubber per acre per annum. There is little evidence regarding average yields to be obtained from a consideration of present day estates approaching the age of twenty years, and that available is contradictory. Some old areas yield remarkably well, while others give comparatively poor yields. There are reliable records(6) of a thirty-seven year old tree giving 392 lbs. 7 ozs. of total rubber in five years, a yearly average of 78 lbs. 8 ozs. There are also reports of old trees in Malaya giving enormous yields, but these cannot be claimed to be authentic. There appears no reason why plantation trees in Malaya should not approach the above standard, and if such yields are possible the policy of rendering the present plantations as permanent as possible should be adopted. At the same time it will be advisable to move cautiously, for observations on one estate, run on up-to-date lines, lead to the conclusion that the yields on

the present plantations with 50–60 trees per acre, begin to decrease after the trees are twenty years old. It must be remembered, however, that these old areas passed through the "boom" period when the only question considered was that of a maximum yield without any regard for the health of the tree, and it is not possible to hazard what effect such treatment would have. Further, root diseases on this area are giving a great amount of trouble, causing continual losses. The question of the permanence of the old trees is closely linked with the possibility of root diseases causing the death of large numbers. These diseases in rubber plantations can be reduced to a negligible quantity if the land is cleared before planting up is commenced, and though the result of clearing plantations now in bearing is more problematical, the estates undertaking this will be fully recompensed by freedom from fungus disease.

If the fungi causing root-rots on old trees become active so as to endanger the plantations at thirty years, a fresh planting scheme must be considered. There are two alternatives:

(*a*) *Re-supplying old areas.*

To re-supply successfully the stumps, lateral roots and logs of all the old trees would have to be burnt off and the ground allowed to lie fallow for at least twelve months, or a subsidiary crop might be grown on the land during this period. If clearing was not thoroughly undertaken, the root-rot fungi would find conditions more favourable for perpetuation and spread than in the previous years, and an exaggerated recurrence of thinning-out conditions would result. Instead of the root-rots becoming serious at ten years old, they might be expected to prove serious much earlier, and numerous young trees would be killed by these fungi.

(*b*) *Planting new areas.*

New contiguous areas opened up near old areas containing diseased trees are doomed to failure unless the latter are cleared. Presumably, the old areas would be gradually abandoned, and in the interests of economy, the rotting trees would be allowed to remain. Such areas would prove to be centres of infection, and it is extremely probable that the new areas would be quickly infected. The parasitism of these fungi may increase in vigour with time, and as observations show, young plants are easily attacked under suitable conditions.

FUTURE RESEARCH.

The evidence favours an endeavour to keep the present plantations active until age prevents the old trees from yielding profitably. Many magnificent looking trees are poor yielders; this fact together with

possible losses from disease has been the great stay for the argument that more trees should be kept to the acre than are absolutely necessary. This is an obvious but clumsy way of insuring a profitable yield, but until a better method is suggested it must remain in force. An optimum number of trees per acre is the ideal—this postulates average yielding trees and few or no losses from disease after the ten years limit is reached. Rubber estates developed with a due regard to hygienic principles need not fear losses from disease as far as present knowledge goes; this statement obtains more support the further investigations are carried.

Fears for the future should not lead rubber people to favour the retention of trees in excess of the optimum, but should stimulate them to insist upon responsible persons finding the ways and means of surmounting the difficulties by approaching cognate problems from different perspectives. The solution lies in the adoption of an intensive scheme of scientific research.

Two lines call for immediate attention: (*a*) physiological investigation to enquire into the rôle played by latex in the metabolism of the tree; (*b*) seed selection investigations with a view to improving yields of latex and at the same time obtaining trees more resistant to fungus attacks. The inception of these investigations would mark a new departure in tropical research. Up-to-date, practical investigations have been all that were asked for; the problems have been so many and the workers so few that immediate matters have had to be hurriedly dealt with, and little attention has been paid to the future. The position is worse because of the lack of correlation in scientific investigations and the difficulty investigators find in meeting and discussing cognate problems from the experience gained in different countries. Rubber research needs centralisation and reorganisation, which would enable immediate practical matters to be grappled with, and would also institute pure scientific investigations with a view to rendering the industry a permanent cornerstone in the edifice of National Industry. With proper foresight and efficient administration, the rubber industry of the Middle East should remain largely under British control, and should fear no competitors. On the other hand, if the present methods continue, the result may be disastrous. The present time is ripe for a departure from archaic ideas, and if all interested parties can be brought together to reasonably discuss the situation, the outcome is assured.

I am indebted to Mr F. de la Mare Norris, Asst. Ag. Inspector, F. M. S., for the drawing of Fig. 20 and to E. W. King, Esq., Visiting Agent to the Kuala Lumpur Rubber Co., for the photograph included as Fig. 2.

Fig. 1

Fig. 2

Fig. 3

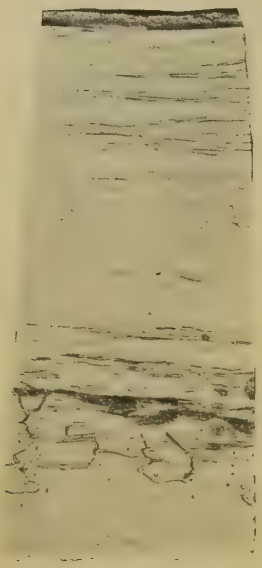


Fig. 4

Fig. 5

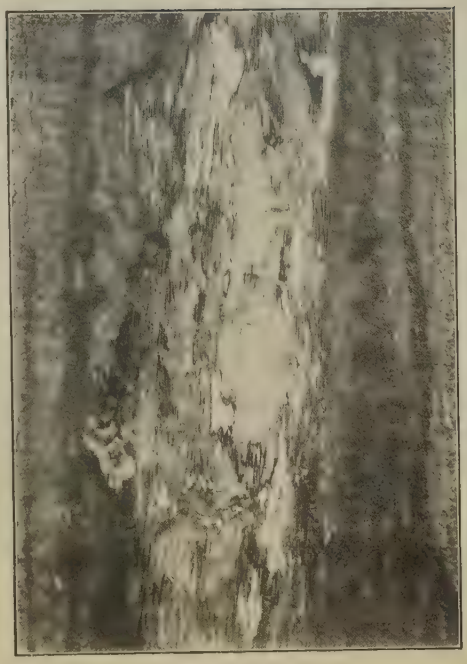


Fig. 6

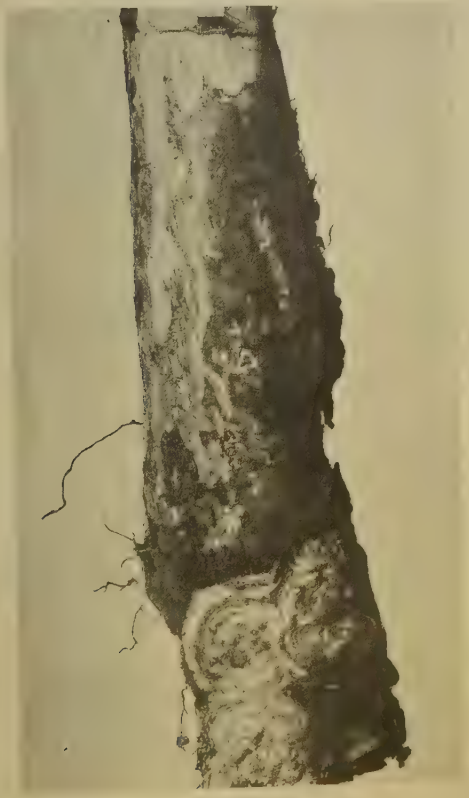


Fig. 7

Fig. 8

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EXPLANATION OF PLATES.

PLATE III.

Fig. 1. Typical specimen of dry collar-rot on ten year old tree caused by *U. zonata*. ($\frac{1}{8}$ nat. size.)

Fig. 2. Flat Plate Fructifications of *U. zonata* on old jungle stump left in Plantation. (Photograph by E. W. King, Esq.)

Fig. 3. T.S. of Spec. (*A*) (see text) attacked by *U. zonata* and shot-hole borer. ($\frac{1}{2}$ nat. size.)

Fig. 4. L.S. of same showing bore-holes and black lines. ($\frac{1}{2}$ nat. size.)

PLATE IV.

Fig. 5. Photograph of scraped tree taken four days after scraping—showing latex exuding from bore-holes. ($\frac{1}{4}$ nat. size.)

Fig. 6. Same tree with bark removed exposing outer surface of wood—note black lines, etc.

Fig. 7. Lateral root carrying typical fructification of *U. zonata*. Note white patches of mycelium in bark; the black lines and zoning on the plates. ($\frac{1}{2}$ nat. size.)

Fig. 8. Hollow White-ant tree with *U. zonata*. The two black lines indicate the limits of the wood attacked by the fungus. ($\frac{1}{8}$ nat. size.)

PLATE V.

Fig. 9. Showing typical flat, zoned fructification. (½ nat. size.)

Fig. 10. Common variation—consisting of stalked individuals aggregated to form a compact mass. At the edges a lichenoid form can be seen, while old plate fructifications are present below but cannot be brought up in the photograph. (½ nat. size.)

Fig. 11. Isolated individual stalked (Xylaria) form—darker area at top indicates the spore bearing part. (Nat. size.)

Fig. 12. Microphotograph of longitudinal section of Fig. 11. The layer above the black line at the top is the spore bearing (conidial) layer.

PLATE VI.

Fig. 13. Another specimen of aggregated stalked form passing into lichenoid type at edges. (½ nat. size.)

Fig. 14. Lichenoid form of *U. zonata* in young condition. (Nat. size.)

Fig. 15A. Upper zoned surface of culture started from conidia.

Fig. 15B. Under surface of 15A—zoning extends through substance of culture.

Fig. 16A. Upper surface showing false zoning of culture started from same source as 15A and 15B.

Fig. 16B. Under non-zoned surface of 16A.

Fig. 17A. Typical zoned culture from collar-rot tree (under surface).

Fig. 17B. Showing typical under-surface of non-zoned culture started from same source as 15A and 16A.

PLATE VII.

Fig. 18. Petri dish zoned culture showing attempt to produce lichenoid form.

Fig. 19. Photograph of section of tree artificially inoculated at the collar. Indicates progress made by fungus in seven months. (¼ nat. size.)

Fig. 20. T.S. of wood of *H. Brasiliensis* attacked by *U. zonata*. Black lines commencing to form in medullary rays (*m*).

PLATE VIII.

Fig. 21. L.S. of scraped tree, see Figs. 5 and 6, indicates progress of fungus in stem in seven months time. (¼ nat. size.)

Fig. 22. Sections of lateral roots showing *U. zonata* travelling in the middle. External tissues apparently healthy. (¼ nat. size.)

Fig. 23. Blocks of rubber wood on which cultures of *U. zonata* have been grown. Split open to show black lines in middle. (Nat. size.)

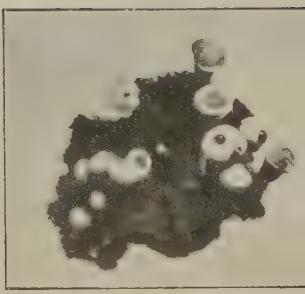


Fig. 11

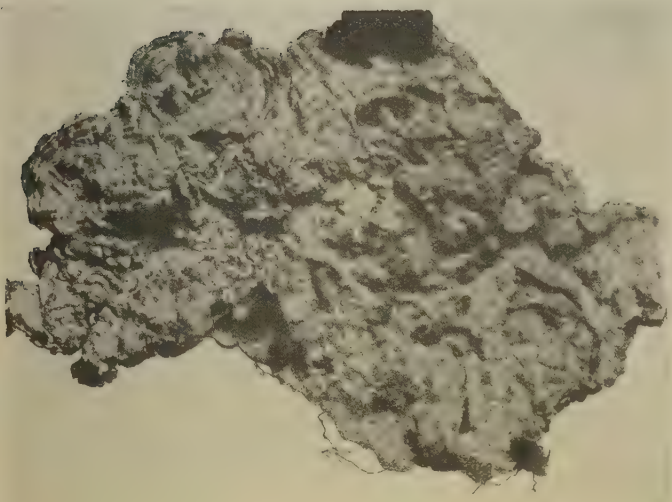


Fig. 9

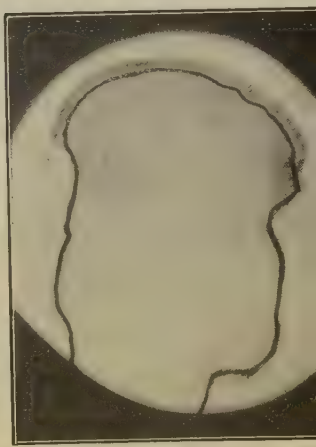


Fig. 12

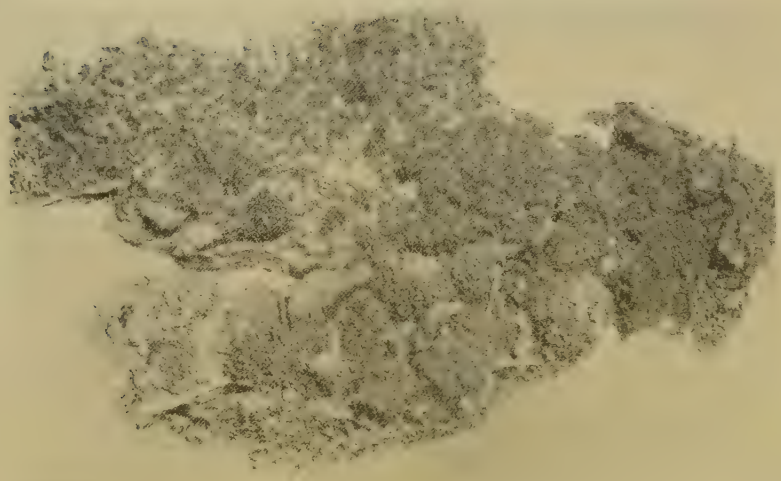


Fig. 10

Fig. 13

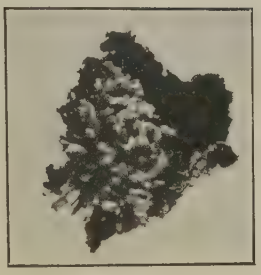
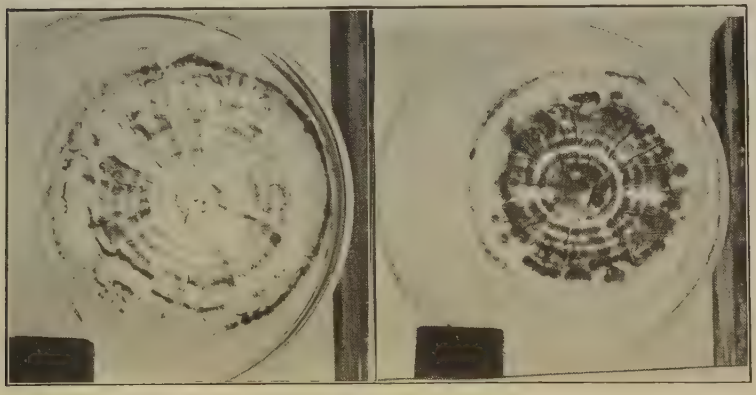
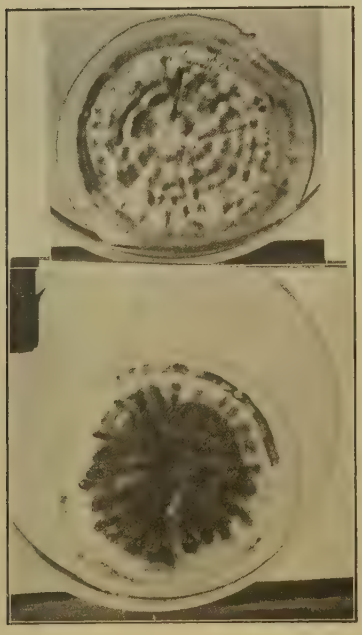


Fig 14



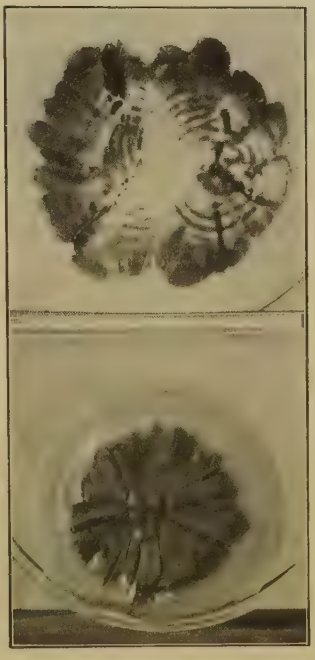
(A) Fig. 15. (B)



(A)

(B)

Fig. 16



(A)

(B)

Fig. 17

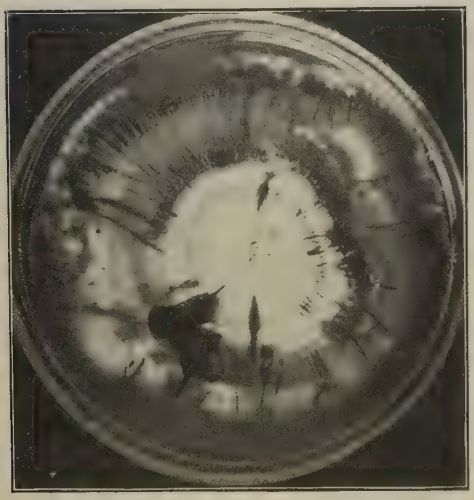


Fig. 18

Fig. 19

Fig. 20

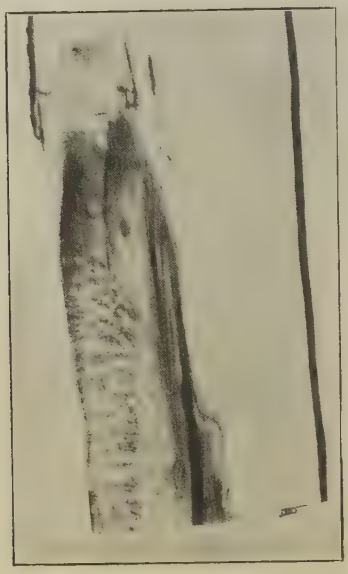


Fig. 21

Fig. 22

Fig. 23

A STUDY OF THE CAPSID BUGS FOUND ON APPLE TREES.

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School of Agriculture, Cambridge.

(With Plates IX—XI.)

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1. INTRODUCTION

The damage done to apples by bugs of the family Capsidae has now become a very serious trouble to fruit growers in this country and a detailed knowledge of those found on apple trees is therefore of immediate importance. This work was undertaken at the suggestion of Fryer who has, during the past few years, made observations on these insects (11, 12, 12*a*).

[1] Mr Husain wishes to thank the Government Grant Committee of the Royal Society for the grant given to him to carry out this work.

The problem has been studied mainly from an economic standpoint, our main object being to find out the amount of damage caused by each species, to study their life-histories and the nature and cause of the injuries done to the leaves, shoot and fruit by the various stages.

Problems of great biological interest and possibly of economic importance have arisen during the course of this work which we have been unable to investigate owing to pressure of time. One season is a very short time to study all the aspects of such a problem as this, and we hope if circumstances permit to continue this work next season. Our justification for the publication of this rather incomplete paper is in the hope that the observations contained in it may be of immediate use in helping to control this serious pest, and also that under such abnormal conditions as exist at the present time, the authors may be unable to continue this work, in which case the observations made may be of some help to future investigators.

A large number of the Capsidae live on the juices of plants which they suck by means of their long rostra, and it is probably as a consequence of this that so many of them have been recorded, some rightly and others wrongly, as plant pests. In America the following have been recorded as damaging fruit trees:

Heterocordylus malinus Reut.
Lygidea mendax Reut.
Lygus pratensis Fab.
Neurocolpus nubilus Say.
Paracalocoris colon Say.

Fryer points out that of these only *Lygus pratensis* is present in this country.

In England the following among others have been recorded as damaging apple trees:

Atractotomus mali Mey.
Lygus pratensis Fab.
Orthotylus marginalis Reut.
Plesiocoris rugicollis Fall.
Psallus ambiguus Fall.

Lygus pratensis is recorded as producing dimples on apples, whereas the others are recorded as damaging the leaves, shoots and fruit.

As Fryer has pointed out (11) there is a great deal of confusion as regards the real pest and the status of the various capsids found so commonly in affected orchards. Unfortunately the presence of a species

on damaged trees seems to have been regarded as sufficient evidence to record it as the cause of the trouble.

Theobald (24–28) repeatedly mentions *Atractotomus mali*, *Orthotylus marginalis* and *Psallus ambiguus* as the culprits. Schöyen (21) mentions *Orthotylus marginalis*, *Plesiocoris rugicollis* and *Psallus ambiguus* as doing damage in Sweden. We do not know on what evidence these statements are based as no details are given, but we have found that it is possible to visit an orchard in which the apples have been badly marked by *Plesiocoris rugicollis* after this species has disappeared and when one or more of the other three species are still present. We think therefore that very probably the damage has been attributed to the wrong species. It is of course possible that in Sweden the injury might be done by a species which is harmless in this country, but in the absence of direct evidence this should be regarded as doubtful.

Fryer has pointed out that *Plesiocoris rugicollis* is the more serious pest and has shown by direct experiment that it causes the typical damage to the leaves, and that *Psallus ambiguus* does not (12). Fryer and Petherbridge also showed by direct experiment that *Plesiocoris rugicollis* damages the fruit and shoot and that *Psallus ambiguus* and *Atractotomus mali* do not (12*a*).

Our experiments and observations show that *Plesiocoris rugicollis* causes marked damage to the leaves, shoots and fruit and is responsible for most of, if not all, the damage in the Wisbech district, and that *Atractotomus mali*, *Orthotylus marginalis* and *Psallus ambiguus* although they feed on the juices of the apple do not cause any apparent damage to the varieties badly marked by *Plesiocoris rugicollis*. In no case have we found either of these three species causing any visible damage to apples.

The life-histories of a number of forms have been worked out in America (6, 7, 16, 18, 29) but very little work has been done in that direction in this country.

2. METHODS.

Observations were made during the season of 1917 chiefly in badly attacked orchards at West Walton near Wisbech where the bugs used for experimental work were also obtained. Observations were also made in unattacked orchards near Cambridge.

April 14th is the earliest record of the hatching of *P. rugicollis* (12) so we started our visits to Wisbech at the beginning of April but obtained no young capsids during the whole of this month. Twigs of apple were brought back and searched for eggs. We could not find the

eggs by means of a surface examination even after cleaning the twigs with dilute potash, but were able to find them by peeling the bark when the eggs remained sticking to it. We kept a number of these twigs in water in the laboratory in the hope that young larvae would hatch out from some of the eggs. Fortunately we were rewarded by getting a number of young *P. rugicollis* larvae (one of which we observed emerging from an egg) from shoots brought in at the end of April.

These started to hatch on May 5th. Up to this date no capsid larvae had hatched at Wisbech, but a visit on May 7th revealed the presence of many newly hatched larvae. The young leaves of the shoots on which they were found were marked with brown spots.

As we were unable to identify the young capsids until later on we classified them under the headings *A*, *B*, *C*, etc. The larvae and nymphs were taken to the laboratory, carefully examined, classified and some of them measured and drawn. Some were preserved, others placed singly on shoots in cages, and others put into sleeves on apple trees, each sleeve containing a single bug. Young bugs were brought in three or four times a week and the development in the laboratory checked by the stages found at Wisbech. All the different stages found were placed on shoots in cages and sleeves and their behaviour noted. We were thus able to find out which of the species did damage and at what stages the damage was done to the leaves, fruit and young stems. Precedence was given to *P. rugicollis* in our observations as this was soon found to be the only culprit. Altogether we had over fifty cages of *P. rugicollis* and about an equal number of the other bugs. We sleeved about fifty *P. rugicollis*, and a large number of the other bugs each in a separate sleeve. We sleeved some *P. rugicollis* singly on black currants and plums, and also took some larvae and nymphs of *P. rugicollis* which were damaging black currants at Histon and sleeved them at different stages on apples.

The sleeves gave very good results and there were very few casualties. We were successful in rearing them in cages, but there were more deaths on account of their drowning or falling down at night. At first we put the twigs in beakers of water with a bug on each twig, but they often crawled down the twigs and got drowned. We then kept the twigs in small flasks of water, plugging the mouth of the flask with cotton wool and placed it in a large beaker covered at the top with a piece of muslin. These cages proved fairly successful, the chief drawback being that the bugs often fell down into the beaker and had to be replaced two or three times a day. The shoots were changed every two or three days in order to keep conditions as normal as possible. In spite of the

difficulties encountered we were able to carry through to the adult stage three individuals of *P. rugicollis* which hatched in the laboratory. From the cage cases we got a complete record of the times of moulting and the duration of each instar which on comparison proved very similar to those under normal conditions at Wisbech. All doubtful cases were discarded and the figures given in Table II (p. 192) are those about which there is no doubt.

The records of the life-history in the cages in the laboratory were compared with the sleeve cases at the farm and with those under normal conditions at Wisbech and were found to agree closely, in the laboratory the hatching and certain moults were in some cases a day or so ahead. We failed to find *P. rugicollis* copulating in spite of the fact that we put males and females together on shoots in the cages. We tried to watch the process of egg laying, but in spite of careful watching we were unsuccessful. For this purpose we had lengths of glass tubing about one inch in diameter, closed at one end by a piece of muslin and at the other by a cork with a hole in it. An apple twig with a ♀ *P. rugicollis* on it was introduced in the tube and the end put through the hole in the cork; the basal end of the twig being outside was placed in water and so kept fresh. A later examination of these twigs showed that eggs had been laid. Some of these twigs with eggs were dissected and photographed.

During the early part of the experiment shoots of Bramley's Seedling, Early Victoria (Emneth Early), Grenadier, Keswick Codling, Lord Grosvenor and Worcester Pearmain were used in the cages, but later on, owing to the difficulty of getting twigs, we had no time to find out the varieties used.

P. rugicollis caused characteristic markings in every case. Details of these markings are given under the description of the injury done by this species.

Psallus ambiguus, *Orthotylus marginalis* and *Atractotomus mali* were at first put on shoots of Keswick Codling and Bramley's Seedling and later on several other varieties, but as far as we could see they did not change the appearance of the leaf or fruit and certainly did not cause any markings of a similar nature to those caused by *P. rugicollis*.

The drawings were done by means of a camera lucida.

A large number of measurements of the different parts are given as the length of a larva or nymph is very variable according to its food supply, a well-fed larva being much longer than a starved individual as in the latter the basal joints of the abdomen become telescoped. Owing to this we subdivided *P. rugicollis* into *A* and *B* and expected to get two

different species. The measurements of the antennae and legs are not so variable.

An account of the life-histories of the various species is given below.

3. CAPSIDS FOUND ON APPLE TREES.

In this country apple trees harbour a fairly large number of the different genera of the Capsidae. From orchards near Wisbech and Cambridge we collected seven different genera and two species of one genus whilst other observers have recorded other species, e.g. *Lygus pratensis*.

The following is a list of the species found:

	District	Numbers	Remarks
Plesiocoris rugicollis	Wisbech	very abundant	affected orchards on apples and currants
	Cambridge	„ „	not found on apples but abundant on currants
Orthotylus marginalis	Wisbech	„ „	affected orchards
	Cambridge	„ „	unaffected orchards
Psallus ambiguus	Wisbech	„ „	affected orchards
	Cambridge	abundant	unaffected orchards
Atractotomus mali	Wisbech	few	affected orchards
	Cambridge	fair number	unaffected orchards
Phytocoris ulmi and *Phytocoris populi*	Wisbech	few	affected orchards
	Cambridge	„	unaffected orchards
Pilophorus perplexa	Wisbech	„	affected orchards
	Cambridge	„	unaffected orchards
Actorhinus angulatus	Wisbech	abundant	affected orchards
	Cambridge	„	unaffected orchards

As pointed out above, of these eight species, *Plesiocoris rugicollis* is the only one which we have found marking the leaves, shoot or fruit and therefore we shall deal with this species in greater detail. The adults of all these genera can be easily identified (Saunders, *Heteroptera*), but it is not always possible to recognise the genus in the earlier stages.

The following characters may be useful in identifying the young stages of the above species:

Plesiocoris rugicollis hatch in April or early in May.

Yellowish green becoming greener at each successive moult.

Terminal joint of antenna pinkish brown.

Lips of dorsal abdominal gland well marked.

Mark the leaves with brown spots.

Orthotylus marginalis hatch about a fortnight later than *P. rugicollis.*

Slightly smaller, orange yellow in first stage, later greenish yellow with bluish tinge, especially marked on lower surface.

Large orange coloured dorsal abdominal gland with faint lips.

Terminal joint of antenna smoky orange. More hairy than *P. rugicollis.*

Psallus ambiguus hatch about the same time as *P. rugicollis.*

Smaller, orange yellow. Terminal joint of antenna smoky orange, and very hairy.

Atractotomus mali (Pl. X, fig. 11) hatch about a month later than *P. rugicollis.*

Small, red, two basal joints of the antenna very much thickened.

Phytocoris populi hatch nearly a month later than *P. rugicollis.*

Large. Antennae and posterior legs long. Mottled, ground colour white with yellow and brown spots; thorax with dark broad lateral bands. Antennae and legs banded and covered with long hairs.

Phytocoris ulmi differs from the preceding in being very much darker. The spots are green, brown and black.

Pilophorus perplexa. Dark reddish brown and bear a marked resemblance to ants with which they are usually found in association. Head large flattened posteriorly and overlaps the front margin of pronotum. A narrow white band across the anal margin of pronotum and a wider white band across the anal half of tergite I. Terminal joint of antenna white.

Aetorhinus angulatus hatches nearly a month later than *P. rugicollis.*

Small, slender, yellowish green, recognisable by its very long antennae and black bases of the tibeae.

4. *PLESIOCORIS RUGICOLLIS* (FIEBER).

Synonymy.

Lygus rugicollis Falléri. Mono. Cimi. p. 76, 1818.
Phytocoris rugicollis Falléri. Hem. Svec. 1. 79. 6.
Capsus rugicollis Schâff. Wanz iii. 80–98, Fig. 299.
Phytocoris marginalis Zelt. I. L. 271, 5.
Plesiocoris rugicollis Fieb. Eur. Hem. 272.
Reuter Cap. 2. 43.
Lygus rugicollis Doug. and Scott. E. M. M. iv. 50.

Adult (Pl. X, fig. 10).

The genus *Plesiocoris* Fieb. consists of only one species. The adult *Plesiocoris rugicollis* is elongate oval; bright green; head, front part of

pronotum, sides of elytra and legs yellow. Sparsely pilose. Elytra sub-parallel in ♂ and comparatively more rounded in ♀.

Head small, with large, dark red, compound eyes, nearly touching the pronotum and projecting slightly beyond its lateral margins. Vertex carinated posteriorly.

Pronotum with a very distinct narrow yellow collar and two very prominent callosities just behind it. Strongly rugose. Posterior margin not emarginate and covers the mesonotum. Sides straight.

Elytra green with yellow margin; sparsely covered with short thick almost black hairs. Membrane hyaline, two cells with green nervures and with a clouded area round the inner angle of the large cell.

Antennae medium length; covered with short thick black hairs and longer and finer light hairs; basal joint green and thicker than the other joints. Second joint longest; lower portion green, upper half dark. Terminal joint three-quarters the length of the third joint, both together shorter than the second; both dark. When cleaned and mounted in balsam terminal and sub-terminal joints pinkish brown.

Legs yellowish green, with short brownish hairs. Tibia with fine brownish spines. Tip of tibia dark and thickly covered with hairs which become thicker and longer as they approach the tip. Tarsi 3-jointed, covered with fine hairs; two basal joints sub-equal, terminal longest; tips dark with curved claws and a pair of transparent arolia.

The Egg.

Time of egg-laying.

The females of *P. rugicollis* brought from Wisbech from about the third week of June to the beginning of July were enclosed in glass tubes with apple twigs, and were observed to have laid eggs in these shoots. In spite of a careful watch, the actual process of egg-laying escaped observation. It may be that the eggs are laid during the early hours of the morning. There is no doubt that they are laid after long intervals, as in a number of cases there were only two or three eggs after a female had been on the twig for over a week. During the egg-laying period the bug keeps feeding on tender leaves and soft terminal parts of the stems which show the characteristic purple-brown spots. It would be interesting to find out the number of days that a female takes to develop eggs after fertilisation and the time taken to lay all the eggs. We are inclined to think that egg-laying continues all through the later part of the life of an adult female.

Position of eggs.

The eggs laid in the laboratory were carefully compared with those dissected out of the twigs brought from Walton, and their identity confirmed by comparison with the eggs dissected out of a female. In all cases the eggs were laid in the present year's soft stem, in many cases very near the apex and in some cases at the thickened bases of the twigs. They were laid indiscriminately in lenticels or in slits made for the purpose in other parts of the stem, preference, however, was given to a wound that had become soft, as shown by the presence of a number of eggs in such situations (Pl. IX, fig. 3). They were usually laid singly, but in some cases more than one egg was found at the same level both in lenticels and wounds. In the latter situation the number may increase to five or six.

After a little practice the position of an egg can be easily detected either as a small brown spot or a little slit in the stem, and under magnification one can easily see the brownish cap of the egg with its whitish rim (see Pl. IX, fig. 2). Only a small portion of the cap if any is above the surface of the stem. The long hairs of the stem, to a large extent, conceal the position of the egg which is often made more obscure by the hairs sticking together on account of the exudation of sap from the wound made in the stem, and by the liquid from the body of the female. After a few months the growth of green algae and particles of dust make it impossible to detect an egg by an external examination of a shoot. But if the bark is peeled off carefully the eggs may be detected on the inner side as they usually come off with it. There are no processes extending out from the egg cap.

Direction of the egg in the stem.

The eggs are laid with their long axes more or less radial to the stem and often penetrate the xylem and in young stems reach the pith. Sometimes they are more tangential and lie wholly in the bark, this is particularly the case when a number of eggs are laid at the same level with their caps close to each other on the surface. They lie somewhat obliquely with their concave side facing the apices of the twigs and the blunt end situated in front of the cap (see Pl. IX, fig. 1). Only in one case was an egg found with its convex side towards the apex of the twig (Fig. 3). The greatest diameter of the egg cap is in line with the long axis of the shoot and only in one case when the egg was laid in the scars of the previous year's bud scales was the long axis of the egg cap at right angles to the long axis of the stem. This can be explained on simple mechanical

grounds. The female must have a strong hold on the stem for the action of its ovipositors and for this it seems necessary that she should hold on in the direction of the stem and not crosswise. Moreover it is easier to separate the fibres of the xylem than to cut across them and a longitudinal slit does not interfere with the growth of the surrounding parts and the egg remains in a fresh condition. The tissue around the egg remains in a healthy condition, except probably around the collar of the egg.

From the position of the egg it would appear that the female faces the base of the twig when ovipositing, and this is borne out by the structure of the ovipositor which is concave on the dorsal side [i.e. posterior side when ovipositing] and by actual observation on the position of an egg which was carried about by a female (its laying in tissue somehow or other interfered with) with its convex side directed ventrally. The direction of the egg shows that the ovipositor acts almost vertically to the stem only a little upward in direction. We cannot suggest any reason for the female facing towards the base of the shoot for oviposition.

Structure of the egg.

The egg has been described by Fryer (12) as somewhat resembling the rubber portion of a fountain pen filler. It is markedly curved along its length, with one end bluntly rounded and thick, and gradually narrowing towards the opposite end forming a neck-like region and slightly expanding into a cap at the top end (see Pl. IX, fig. 4 *A*). The egg is cream coloured, the surface is smooth and glistening and the shell is strong and elastic. The body of the egg is slightly flattened by the fibres of the plant pressing against it. This part of the egg is thus oval in cross-section becoming almost circular in the region of the neck. The cap is dark brown in colour and strongly chitinized. It shows strongly marked longitudinal striations all round, which are probably hairs that hold the cap to the egg-shell and at the base of it are seen a few scale-like markings. The function of these markings is obscure. The opening of the egg is closed by a strong oval disc, brown in colour and showing curious processes on both surfaces. The outer rim of the cap is whitish with radially arranged lamellar-like structure when seen from above.

As mentioned above, the egg dissected out of a twig is flatter than one dissected out of a female. It measures 1·4 mm. in length, 0·3 mm. at its greatest width, and 0·25 mm. in the region of the neck.

In the body of a mature female the eggs lie in longitudinal direction, all with their caps pointing forwards. The whole body is practically full of eggs, which reach right up to the prothorax. The largest number

dissected out of one female was fourteen, but it is probable that the actual number is more than this.

The eggs live in the shoots all through the winter and the young larvae hatch from them the following April or May.

Description of the Instars.

Instar I (Pl. IX, fig. 5). Length 1·1–1·4 mm., small, slender, fragile, semi-transparent. When just hatched pale yellow, turning greenish and darker in a few hours. On the head and thorax are smoky patches interrupted on the thorax by a mid-dorsal pale line which bifurcates on the head at the level of the eyes. The smoky colour is in the chitin whilst the actual colour of the bug is due to pigments in the tissues of the body.

Head relatively large, marked longitudinal groove just in front of vertex; yellow, with smoky shades interrupted by a Y-shaped pale line. A row of short thick black hairs is present on the vertex and a few longer hairs on the front of the head. Eyes, compound, large, deep carmine in colour, nearly touching the pronotum.

Thorax increases in width up to the metathorax.

Pronotum almost rectangular, anterior margin slightly curved, angles rounded. Light green with smoky patches interrupted by mid-dorsal pale line. Row of hairs on posterior margin and a few irregularly scattered hairs.

Mesothorax with smoky patches; broader than prothorax.

Metathorax shortest and broadest, smoky patches narrower.

Abdomen pyriform, slightly longer than broad; greatest breadth across segments II–IV. (In a well-fed individual the abdomen is distended and almost circular in cross-section; but in a starved specimen it becomes flatter and the first two abdominal segments become telescoped.) Yellowish green, with a pale line extending from segments III–X, smoky patch on segment I. A large circular yellow area is present in the mid-dorsal region of segment III. This is the pocket-shaped dorsal abdominal gland seen through the cuticle; its orifice is between segments III and IV; the anterior lip is the black thickened part of the anal margin of tergite III. The anterior part of tergite IV opposite this is dark and the two lips enclose a light coloured area. A row of thick short black hairs on each tergite, longer on segments VIII–X; segment IX also has a number of small hairs. Whole abdomen covered with a fine fur of setae.

Appendages.

Antennae medium-sized, slender, at first pale yellowish green,

later dusky. Terminal joint yellow at base, changing into orange, pinkish brown, orange and yellow towards the tip. This pinkish brown colour is characteristic of all the instars of this species. Terminal joint longest; 1½ times that of the third joint and slightly thicker. It is thickly covered with hairs, other joints fewer hairs.

Legs short, thick, at first pale, then turn yellowish green and dusky, tarsi almost black. Femora light green with a few black hairs slightly longer than those on the body. Tibia slender with more and longer hairs. Tarsi 2-jointed, the terminal joint being the longer. Two black curved claws with transparent aroliae.

Proboscis greenish yellow with a black tip; reaches to about the middle coxae.

Instar II (Pl. IX, fig. 6). Length 1·5–2·2 mm. Resembles Instar I in shape. At first yellowish with transparent appendages but soon becomes darker. The body is distinctly greener than Instar I. The smoky shades present on the head, thorax and abdomen are now absent. The pale mid-dorsal line on the abdomen and thorax bifurcating on the head is still present.

Characteristic differences. Nearly double as long. Terminal joint of antenna slightly longer than joint II; joint II distinctly longer than joint III. Posterior margin of mesonotum slightly emarginate.

Head large, no groove present; yellow with Y-shaped pale line present. Eyes deep red, and the number of facets has increased.

Thorax, shape as Instar I.

Pronotum trapeziform, anterior margin slightly narrower than the posterior; two callosities present.

Abdomen pyriform; longer than broad. No smoky shade on segment I. The yellow mid-dorsal abdominal gland is still present on segment III and its lips are well marked.

Appendages.

Antennae medium sized, slender—colour as in Instar I; basal joint thickest; terminal joint longest, slightly longer than joint II.

Legs similar to Instar I but longer.

Proboscis reaches to about the middle coxae, colour as in Instar I.

Instar III (Pl. X, fig. 7). Length 2·1–2·8 mm. Outline and colour as Instar II; mid-dorsal line faint.

Characteristic structural peculiarities. The second joint of the antenna has increased relatively more than the other joints. Terminal joint of

antenna now shorter than the second joint which is the longest; the third joint shorter than the fourth. Wing pads, small thickened lobes at the posterior angles of meso- and metanotum, the former being slightly larger. The wing pads become darker when the nymph is about to moult. Other characters similar to Instar II, the yellow spot on the abdominal segment III being rather faint.

Instar IV (Pl. X, fig. 8). Length 1·33–1·99 mm.

Characteristic structural peculiarities. A further increase in the relative

Table I. *Plesiocoris rugicollis* (measurement in millimetres).

		Instar I	Instar II	Instar III	Instar IV	Instar V	Adult
Head	Length	·21	·34	·43	·52	·54	·56
	Width	·4	·52	·64	·79	·9	·99
	Distance between eyes	·26	·34	·39	·45	·5	·5
Prothorax	Length	·21	·26	·31	·4	·6	—
	Width	·38	·55	·69	·86	1·15	—
Mesothorax	Length	·14	·19	·28	·43	·67	—
	Width	·48	·6	·86	—	—	—
Metathorax	Length	·12	·14	·17	·17	·19	—
	Width	·49	·66	·88	—	—	—
Wings	Length	—	—	—	·85	1·7	—
	Width	—	—	—	1·4	1·8	—
Abdomen	Length	·43–·73	·8–1·29	1·1–1·47	1·33–1·9	1·9–2·37	—
	Width	·57	·69	·95	1·3	1·7	—
	Total length	1·1–1·4	1·5–2·2	2·1–2·8	2·7–3·4	3·6–4·27	5·9–6·0
Antennae	1	·14	·17	·22	·29	·38	·55
	2	·20	·34	·54	·86	1·3	1·81
	3	·17	·26	·40	·57	·76	·91
	4	·31	·40	·45	·52	·57	·70
	Total length	·82	1·17	1·61	2·24	3·01	3·8
Leg I	Femur	·25	·41	·52	·69	·78	1·29
	Tibia	·34	·46	·66	·83	1·1	1·6
	Tarsus	·19	·24	·28	·34	·43	·58
Leg II	Femur	·31	·46	·6	·83	1·1	1·48
	Tibia	·38	·55	·78	1·09	1·48	1·82
	Tarsus	·2	·25	·28	·39	·5	·62
Leg III	Femur	·36	·47	·69	·94	1·2	1·85
	Tibia	·45	·69	·98	1·5	1·95	2·92
	Tarsus	·22	·29	·34	·45	·55	·68
Rostrum	1	·16	·20	·26	·32	·41	·49
	2	·13	·18	·21	·27	·34	·44
	3	·1	·13	·16	·24	·31	·42
	4	·18	·21	·27	·32	·41	·53
	Total length	·56	·70	·87	1·1	1·39	1·84

length of the second antennal joint; the third joint is now longer than the fourth. A change in the shape of the thorax, owing to the increase in size of the wing pads which now reach the second abdominal segment. Other characters as in Instar III.

TABLE II. *PLESIOCORIS RUGICOLLIS.*

Stages	Dates of hatchings and of the various instars	Duration of each instar	Records of hatchings and moults obtained in the laboratory	
Hatching	*May 5th–13th	—	—	—
Instar I	present from May 5th–18th	6 days	Hatching 5. v. 17 5. v. 17 5. v. 17	1st moult 11. v. 17 11. v. 17 11. v. 17
Instar II	present from May 11th–23rd	4–5 days	1st moult 11. v. 17 11. v. 17 11. v. 17 12. v. 17 12. v. 17	2nd moult 14. v. 17 15. v. 17 15. v. 17 16. v. 17 17. v. 17
Instar III	present from May 15th–28th	6 days	2nd moult 14. v. 17 15. v. 17	3rd moult 20. v. 17 21. v. 17
Instar IV	present from May 20th–June 3rd	5–7 days	3rd moult 20. v. 17 20. v. 17 24. v. 17 24. v. 17 25. v. 17 31. v. 17	4th moult 26. v. 17 25. v. 17 30. v. 17 31. v. 17 31. v. 17 6. vi. 17
Instar V	present from May 25th–June 9th	6–7 days	4th moult 25. v. 17 28. v. 17 31. v. 17	5th moult 1. vi. 17 4. vi. 17 6. vi. 17
Adult	present from June 1st–July 21st	about 6 weeks	—	—

* Fryer records these larvae as hatching before April 14th in 1913.

Instar V (Pl. X, fig. 9). Length 1·9–2·37 mm.

Characteristic peculiarities. Colour greener than in previous stages; second joint of antenna very long, nearly equal to the third and fourth together. Wing pads larger and reach the fourth abdominal segments. Yellow spot on abdominal segment III not noticeable. Other characters as in Instar IV.

Habits.

Plesiocoris rugicollis hatches out after the buds of the apple have opened and about 16–17 days before the flowers are in full bloom. Very soon the young larvae move to the opening buds and begin to feed on the tender opened or half-opened leaves which at this stage are not more that about an inch in length. On the opened leaves they usually feed from the upper surface more especially on each side of the mid-rib of the basal half of the lamina (see Pl. XI, fig. 12). They also feed on the upper surface of the rolled opening leaves and here they are partially concealed. Every leaf where they feed soon shows the characteristic brown spots. On being disturbed they run away very quickly and conceal themselves either in the curled leaves or the axils of the opened leaves. It is difficult to shake them off a branch at this stage, even when falling from one of the upper branches of a tree they hardly ever reach the ground but obtain a hold on one of the lower twigs either by means of their sharp claws or by extruding the posterior part of their alimentary canal which secretes a sticky fluid. The hairs on the leaves and stems of the apple seem to help them in regaining their hold as they are more easily shaken off the black currant. The later instars are more easily shaken off. At all stages they run very quickly but seem to be more active during the younger stages. They dodge like a squirrel by running to the opposite side of the stem and it is often difficult to catch them.

They share with other insects the habit of cleaning their antennae by means of the hairs at the ends of the front tibiae after which they often rub their tibiae against each other. They moult in any situation, cast skins having been found on both surfaces of the leaves, on the petioles and on the stems. When ready to moult they become very sluggish and stop feeding. Moulting takes place by a longitudinal slit in the mid-dorsal region of the thorax, this being preceded by a throbbing in the region of the callosities on the pronotum. The thorax and part of the head and abdomen come out first, followed by the legs and antennae and lastly by the rostrum. After moulting the bugs feed voraciously, making repeated stabs at the leaf at the rate of about fifty per hour.

The adults are easily shaken from the trees.

In walking through an infested orchard we have never seen them flying from one tree to another, but they can fly a fair distance when disturbed. When shaking them from a tree into a Bignell beating tray they often fly back again into the tree before reaching the tray and some of those which reach the tray fly back to the tree again. In the laboratory they

usually flew towards the window in an almost horizontal direction, but some flew upwards and a few reached the ceiling.

Time and nature of injury.

In 1917 a very severe and prolonged winter was followed by a warm spring, the former retarding the opening of the buds and also the hatching of *P. rugicollis*. Fryer records them as hatching before April 14th in 1913 and in 1916 a few newly hatched bugs were found on April 25th. In 1917 the first markings were seen on May 7th, but under warmer conditions in the laboratory a few hatched on May 5th. At this date the buds were opening rapidly, the diameter of well-opened buds being about one inch and a half, with the outer leaves about an inch long. The first attack started immediately after hatching and in a day or two a large number of buds showed the characteristic purple brown markings on their leaves. The number of attacked buds continued to increase rapidly on account of new larvae which kept hatching until May 13th and also because the earlier hatched larvae moved from one bud to another. It is probable that the hatching period, May 6th–May 13th, is shorter than the normal period owing to the warm condition obtaining at this period in 1917.

In some varieties and notably Lord Derby the leaves remained curled much longer than in other varieties and provided more shelter for the bugs. The time of full bloom of Early Victoria, Lord Grosvenor and Lady Hollendale was on May 23rd, i.e. about seventeen days after the bugs started to hatch and during this time the leaves were the source of food. In some varieties, e.g. Grenadier, the opened leaves were soon used up as a source of food and were very badly damaged, the bugs then began to feed on the closed part of the buds. This variety received a very bad check from the marking of the young leaves which did not expand to any extent (see Pl. XI, fig. 14 B).

When the fruit set the bugs were mostly in the fourth instar, some third and fifth instars also being present. These bugs began to mark the fruit on May 28th, very soon after setting. All the last three nymph stages and the adults damage the fruit. In cages in the laboratory they did not show any marked preference for the fruit but fed upon leaves and fruit alternately and seemed to be quite satisfied to feed at the place where they were put, except on old leaves.

They did not attack the fruit after it was over an inch in diameter but turned their attention to the young leaves and succulent part of the stem. When the adults appear the fruit is a fair size and not much

damage is done to it by them, but the adults do most of the damage to the shoots. Where the young stem is attacked a brown fluid oozes out, the stem often cracks and is in some cases killed. When the terminal shoot is killed several of the buds below form shoots and a very thick tree results, especially when young trees are attacked. Most of the damage to the fruit is done by the Instars IV and V.

Wherever a *P. rugicollis* in any stage sucks a leaf a purplish brown spot appears after a short time, at first round but soon becoming irregular. The spot becomes irregular by spreading to the nearest small veins which form the boundaries of the spot and thus the shape of the marking is determined by the small veins between which the puncture is made. The area covered by the spot becomes thinner and sinks below the normal level of the surface of the leaf.

In older leaves the marking does not spread much but remains as a small spot. In all cases cork formation takes place round the seat of injury. When the puncture is very deep the whole of the mesophyll is affected, but in some punctures from the upper surface only the upper part of the mesophyll was injured and in some punctures from the lower surface only the lower part of the mesophyll turned brown. In many cases the epidermis over the brown spot appeared to be normal. Sections of injured leaves show that the mesophyll dies first and the epidermis afterwards. A badly damaged leaf sometimes remains shrivelled and eventually dies. Some badly damaged leaves do not die but remain crumpled and deformed, the dead tissue falling out and leaving a number of holes with a brown margin. In several trees of the variety Grenadier the leaves were so badly punctured that very little growth was made until late in the season. In a mild attack the leaves may grow fairly well whilst showing the small brown marks. Occasionally a vein is punctured and a brown spot results.

The injury to the fruit varies with the variety. In the slower growing varieties like Lady Hollendale and Worcester Pearmain the damage is enormous and badly marked apples do not grow even to one-quarter of their normal size and often fall off. In the quicker growing varieties like Bramley's Seedling and Early Victoria the fruit grows out of the injury more, and although corky markings and peculiar shaped apples may result, the reduction of the crop is not nearly so marked.

When a bug punctures the young fruit a small drop of fluid exudes from each puncture. These drops eventually dry up and leave a brown mark in the fruit (see Pl. XI, fig. 13). The tissue around the seat of injury forms cork and is therefore prevented from making normal growth,

dimpled or malformed fruit resulting. In a young apple the injury extends several cells below the cuticle, but in an old apple there is no discoloration of the flesh under the cork layer.

Punctured apples in their late stages show a russetting due to the brown cork scars and in some varieties they crack badly. Practically all the damage to the fruit is done before it reaches an inch in diameter, probably because later on it is too hard to be easily punctured. In one or two cases adults were found dead with their probosces inserted into the tissue of medium-sized fruits. Cork formation follows the punctures in leaves, fruit and young shoots.

The cause of injury.

It has been suggested (1, 14) that the injury done by a capsid is due to the mechanical laceration of the tissues by the barbed stylets of its rostrum. There is no doubt that the ends of the stylets are barbed and that the bug does puncture the plant repeatedly, but how far this laceration is responsible for the brown spots or any other external sign of damage is difficult to say. A number of different capsids were found feeding on the same trees but only in the case of *P. rugicollis* was any visible damage done.

The stylets of all these capsids are very similar and it seems to us that the cause of the damage is chemical rather than mechanical, the salivary injection from *P. rugicollis* being lethal to the tissue of apple trees whilst that of the other species is not. This is supported by the fact that it is the mesophyll and not the epidermis which shows the first signs of injury, and dead mesophyll may be present under a healthy epidermis, and again the damaged area may spread for some time after laceration has taken place.

This brings us to an interesting biological problem. The injury done to a plant may be mechanical or physiological, and although the final result to the plant may be the same it seems necessary to distinguish these two kinds. The term "mechanical injury" might be used to include the wounding of plants by eating away parts of them or by sucking the juices. The term "physiological injury" might mean the injection of some material into the plant which kills the tissue or brings about abnormal growth. The same species might be responsible for both mechanical and physiological damage.

It seems probable that in the case of *Plesiocorus rugicollis* the mechanical injury is of little consequence. *Psallus ambiguus* and *Orthotylus marginalis* were sometimes as numerous as that species and

yet the injury caused by their sucking the juices was of no importance. An insect that causes mechanical injury would probably do so to all plants that it feeds on but it is possible that the injection of an insect that causes physiological injury might affect different plants in different ways and even be harmless to some plants and also much less harmful to some varieties of plants of the same species.

It is interesting to find that certain pests are specific in their attacks whereas others infect a large number of plants. *Lygus pratensis* is known to attack fifty different species of plants(5). *Plesiocoris rugicollis* was formerly known to attack *Salix* and *Alnus* but it now attacks apple, black and red currants and under experimental conditions has been made to attack plums. This interesting change in the diet of a species is possibly comparable with mutations in the morphological characters and may be due to some physiological mutation in the organism. It is possible that *P. rugicollis* may in the future extend its host plants and so become a still more serious pest.

The change in its diet is difficult to explain but it may be due to a very simple cause. Larvae cannot fly and when just hatched do not appear capable of travelling far, and their only chance of living seems to be to suck the juice of the plant on which the eggs are laid. They get used to this diet and so do not change it readily. Suppose a fertilised female to be blown on to a new host and not capable of reaching her former host, she may lay eggs there and if she can live on the juices of this host the larvae which hatch from these eggs will probably be able to live on the tissues of the host on which their mother could live, and in any case are unable to reach the original host of their mother. Actual experimental evidence is wanting, but we know that nymphs can be made to change their hosts, e.g. apple to plum, and black currant to apple, and it would be interesting to see if *P. rugicollis* could be made to lay eggs on a species other than that on which it was reared.

The facts that apples and willows are found interlacing and only the willows attacked by *P. rugicollis* and also apples and black currants interlaced with only the latter attacked show that it normally lays its eggs on the host on which it has fed and does not readily change its host when that host is capable of providing it with food.

In the Wisbech district *P. rugicollis* lives on willows, apples, black currants and red currants, whereas in certain districts near Cambridge it does not live on apples but does on the other three. Larvae from black currants near Cambridge were sleeved on apple trees and although they did not feed readily at first eventually became used to their new host

and completed their development. They begin to feed more readily if transferred in the early larval stages than in the later stages. Larvae from apples also reached the adult stage when sleeved on black currants. In an orchard at Great Eversden where for several years black and red currants have been attacked, this year the rows of apples near them, Worcester Pearmain, are also attacked.

The black currant leaves are much thinner than apple leaves and consequently the brown marks caused by the bugs soon fall out and leave holes with a brown margin.

Larvae of *P. rugicollis* when sleeved on plum caused a few markings but did not live long. The injury was similar in appearance to that of black currant.

Taylor (23) and Collinge (5) attribute the dimples in apple fruit to the eggs of *Lygus pratensis* which are also laid in the stalk of the fruit which may consequently fall off. This is not the case with *P. rugicollis*.

Control.

It has been shown by experiments (12, 12*a* and some carried out in 1917 by one of us) that *P. rugicollis* can be kept in check by spraying with "soft soap and nicotine." The amount of soft soap necessarily varies with the hardness of the water, 1·0 per cent. or even less is sufficient for soft water but it may be better to use more than this for hard water. 0·05 per cent. of nicotine (98–99 per cent.) is sufficient. This wash kills the bugs very quickly in all stages except the egg stage.

In order to have its maximum effect the wash should be applied just after all the bugs have hatched and spraying may continue for some time after the fruit has become marked. It is necessary to spray with a powerful jet and for this purpose a high pressure pump and a fairly coarse nozzle should be used. The trees should be thoroughly drenched and sprayed in a *downward* direction, keeping the nozzle fairly close to the opening leaves.

As the eggs are laid in the young shoots, trees from an infested nursery should not be planted in non-infested areas.

5. SUMMARY OF THE LIFE-HISTORY OF A CAPSID.

Although these bugs do not undergo a sudden change at any moult, yet each stage possesses characteristic features. The following is a brief summary of these peculiarities founded on the study of the capsids dealt with in this paper and others that have come under our notice and will be applicable to a large number of species.

Instar I. Smoky shade on dorsal surface of head, thorax and first abdominal segment, interrupted in the region of the thorax by a mid-dorsal pale line which continues on the head and bifurcates at the level of the eyes (see Pl. IX, fig. 5).

Longitudinal groove present on the head.

Terminal joint of antenna the longest.

Instar II[1] (Fig. 6). No smoky shade.

Terminal joint of antenna slightly longer than the second.

No wing pads.

Instar III (Pl. X, fig. 7). Small but distinct wing pads.

Second joint of antenna the longest.

Instar IV (Fig. 8). Wing pads reach second abdominal segment.

Second antennal joint relatively longer.

Instar V (Fig. 9). Wing pads reach fourth abdominal segment.

Second antennal joint still longer.

All these instars have 2-jointed tarsi.

6. *ORTHOTYLUS MARGINALIS* REUT. (*NASSATUS* FALL. ET AUCT.).

This species hatches about a fortnight later than *P. rugicollis* and *Psallus ambiguus*. The adult resembles *P. rugicollis* in its green colour but can be readily distinguished from it by the absence of a collar and the two callosities on the pronotum; it is moreover covered with fine white hairs. The eyes nearly touch the pronotum.

The antennae are slender, medium sized, with the basal joint somewhat pale in both sexes, and the terminal joint with no pink colour.

A very distinct orange spot is present between the last two pairs of coxae.

Male with asymmetrical genital forceps, that of the left side having two conspicuous prongs.

It is mentioned by Theobald (24, 28) and Schöyen (21) as a pest of apples but we find no evidence for this. We have found it in considerable numbers in uninjured orchards.

The egg of *Orthotylus marginalis* is smaller than that of *P. rugicollis*, being only 0·95 mm. in length. It resembles the rubber part of a fountain pen filler with the open end flattened laterally.

It differs from the egg of *P. rugicollis* in that the transverse section of the cap is much longer than it is wide and the cap itself is convex.

It is slightly curved in the region of the neck (cf. Pl. IX, figs. 4 A and B).

[1] Crosby and Leonard's (7) third and fourth stage are alike and what they describe as second stage is really the third.

We dissected out eggs from a female but did not find any eggs in the stems. Females were put on shoots in cages but we were unable to find any eggs in these shoots.

The eggs are undoubtedly laid in the stems because the larvae hatch out on the twigs.

Instar I. Length 1·17–1·26 mm.

In shape very similar to Instar I of *P. rugicollis* but smaller and distinguishable by the bright orange-yellow dorsal abdominal gland, which

TABLE III.

ORTHOTYLUS MARGINALIS (MEASUREMENTS IN MILLIMETRE).

		Instar I	Instar II	Instar III	Instar IV	Instar V	♂	♀
Head	Length	·24	·31	·39	·52	·55	·58	·6
	Width	·38	·5	·63	·79	·90	·94	1·02
	Distance bet. eyes	·2	·28	·39	·45	·52	·44	·52
Prothorax	Length	·17	·24	·31	·39	·58	·85	—
	Width	·4	·55	·66	·83	1·2	1·3	—
Mesothorax	Length	·13	·18	·25	·41	·62	—	—
	Width	·45	·66	·85	—	—	—	—
Metathorax	Length	·08	·11	·15	·17	·17	—	—
Wings	Length	—	—	—	—	1·6	4·8	—
	Width	—	—	—	1·2	1·9	2·1	—
Abdomen	Length	·55–·69	·76–·95	·86–1·16	1·3–2·0	1·9–2·0	—	—
	Width	·48	·75	1·0	1·1	1·5	—	—
	Total length	1·17–1·26	1·6–1·8	1·9–2·4	2·7–3·5	3·9	6·23	—
Antennae	Segment 1	·1	·13	·18	·28	·39	·50	
	„ 2	·17	·26	·46	·82	1·3	1·85	
	„ 3	·13	·22	·34	·58	·79	1·02	
	„ 4	·25	·31	·39	·47	·55	·66	
	Total length	·67	·96	1·37	2·12	3·33	4·03	
Leg I	Femur	·24	·37	·5	·7	1·0	1·25	
	Tibia	·26	·4	·57	·8	1·1	1·46	
	Tarsus	·15	·18	·25	·29	·38	·46	
Leg II	Femur	·24	·4	·5	·82	1·1	1·46	
	Tibia	·29	·45	·63	·94	1·3	1·72	
	Tarsus	·15	·18	·25	·32	·41	·47	
Leg III	Femur	·29	·45	·56	1·0	1·5	2·00	
	Tibia	·34	·6	·93	1·4	2·0	3·00	
	Tarsus	·17	·27	·31	·40	·52	·63	
Proboscis	1	·18	·2	·24	·34	·44	·51	
	2	·08	·15	·19	·27	·36	·44	
	3	·07	·12	·17	·23	·29	·40	
	4	·17	·19	·21	·29	·37	·42	

is easily seen by the naked eye through the chitin. Lips of this gland very light brown and not so noticeable as in *P. rugicollis*.

Yellowish green in colour, eyes dark red with a white margin round them. Thorax and abdomen covered with long white hairs. Antennae light orange with a dusky chitin; terminal joint of same colour, not pink as in *P. rugicollis*. Other characters typical of first Instars (see p. 199).

Instar II. Length 1·6–1·8 mm.

Peculiarities typical of Instar II (see p. 199), otherwise as Instar I except for a slight bluish tinge, especially underneath.

Instar III. Length 1·9–2·4 mm.

Peculiarities typical of Instar III (see p. 199), otherwise as previous instar.

Instar IV. Length 2·7–3·5 mm.

Peculiarities typical of Instar IV (see p. 199), otherwise as previous instar.

Instar V. Length 3·9 mm.

Peculiarities of Instar V (see p. 199), otherwise as previous instar.

The last three instars have a definite bluish tinge.

7. *PSALLUS AMBIGUUS* (FALL.) (*OBSCURUS* D. AND S.).

This species hatches out about the same time as *P. rugicollis*. A large number were found in the orchards at West Walton. They are very shy during the first two stages and lie concealed in the axils of the leaves and it is very difficult to see them and still more difficult to dislodge them by beating or shaking. They were found equally frequently in damaged and undamaged buds, and their behaviour in cages and in sleeves definitely proved that these were not associated with the injury done to the leaves and fruit. They were present at the University Farm, Cambridge, and at Histon where there was no trace of damage. We found them too frequently on apple shoots brought for our cages, but never found any damage on these and consequently we regard this species as harmless. One fact is very significant and requires elucidation. As pointed out above the larvae of *Psallus ambiguus* lived for weeks on absolutely dried shoots with no leaves and several of them reached the fourth instar stage. This suggests that their source of food may be something other than plant juices. There were present on these twigs, eggs and nymphs of the apple sucker (*Psylla mali*) and also eggs and young of the red spider (*Tetranychus* sp.). There is no doubt that they do suck plant juices as we have seen them doing so, but we have also

seen them sucking the dead bodies of other capsids and it seems probable that they may be carnivorous and consequently beneficial.

The duration of each instar is very much the same as in the case of *P. rugicollis*.

Instar I. Length 1·0–1·4 mm.

Yellow, eyes crimson with a white edge round them.

Thorax and abdomen covered with long white hairs.

TABLE IV. *PSALLUS AMBIGUUS* (MEASUREMENTS IN MILLIMETRES).

		Instar I	Instar II	Instar III	Instar IV	Instar V	Adult
Head	Length	·24	·31	·35	·4	·43	·43
	Width	·37	·48	·57	·69	·8	·86
	Distance between the eyes	·28	·31	·34	·4	·45	·45
Prothorax	Length	·17	·26	·29	·43	·48	·72
	Width	·37	·51	·59	·76	1·0	1·6
Mesothorax	Length	·12	·17	·25	·37	·57	·81
	Width	·45	·6	·68	—	—	—
Metathorax	Length	·11	·12	·13	·15	·15	—
	Width	·51	·67	·75	—	—	—
Wings	Length	—	—	—	·77	1·4	3·41
	Width of body in the region of wings	—	—	—	1·1	1·5	1·8
Abdomen	Length	·48–·62	·8–·88	·94–1·1	1·3–1·6	1·7-1·9	—
	Width	·56	·68	·85	1·2	1·4	—
	Total length	1·0–1·4	1·6–1·8	2·1–2·3	2·6–3·1	3·28–3·6	4·5
Antennae	1	·07	·14	·16	·2	·28	·36
	2	·15	·28	·4	·6	·85	1·17
	3	·13	·22	·31	·4	·52	·58
	4	·25	·31	·28	·32	·36	·4
	Total length	·60	·95	1·15	1·52	2·11	2·51
Leg I	Femur	·27	·34	·41	·54	·7	·9
	Tibia	·3	·36	·5	·54	·81	1·1
	Tarsus	·16	·19	·22	·27	·3	·36
Leg II	Femur	·28	·36	·51	·63	·9	1·0
	Tibia	·32	·43	·58	·72	1·1	1·4
	Tarsus	·16	·19	·23	·28	·35	·38
Leg III	Femur	·39	·41	·63	·8	1·1	1·4
	Tibia	·43	·5	·79	1·1	1·62	2·1
	Tarsus	·19	·23	·28	·36	·49	·58
Proboscis	1	·16	·20	·27	·3	·41	·45
	2	·12	·15	·19	·27	·38	·41
	3	·09	·12	·18	·23	·30	·36
	4	·18	·21	·27	·3	·40	·45

Yellow dorsal abdominal gland with faintly marked lips.

Antennae pale orange with a dusky shade in the chitin; terminal joint of same colour, not pink as in *P. rugicollis*.

Other characters typical of first Instars.

Instar II. Length 1·6–1·8 mm.

Peculiarities typical of Instar II (see p. 199), otherwise as Instar I.

Instar III. Length 2·1–2·3 mm.

Antennae darker, basal joint darkest.

Head yellow; thorax and abdomen greyish yellow with a green tinge.

Eyes dark red with a white margin.

Peculiarities typical of Instar III (see p. 199), otherwise as Instar II.

Instar IV. Length 2·6–3·1 mm.

Peculiarities typical of Instar IV (see p. 199), otherwise as Instar III.

Instar V. Length 3·28–3·6 mm.

Peculiarities typical of Instar V (see p. 199), otherwise as Instar IV.

Adult. Length 4·5 mm.

Oval; ♂ dark brown; ♀ varies from grey to dark brown, cuneus always reddish.

Body covered with long pale hairs which easily rub off.

No collar on pronotum.

8. *ATRACTOTOMUS MALI* (MEY.).

This species has been accused of doing great damage to the apple in Suffolk and Hereford(26) but in all our experiments we have found it to be quite harmless. It was not found in any great numbers either at Wisbech or at Cambridge, but the trees on which they were found in fair numbers, two or three on one shoot, showed no marks or signs of injury. While one *P. rugicollis* larva would cover two or three fair sized leaves with brown spots in one night, two even three or four nymphs kept in cages for days on the same shoot did not mark them. We regard this species as quite harmless.

Instar V (Pl. X, fig. 11). Small, broad, ovate nymph, with deep dark red colour, very dark on the anterior part of pronotum, wing pads and two basal antennal joints.

Antennae medium sized with two basal joints very thick and dark red, thickly covered with black hairs.

The two terminal joints cream coloured with a faint tinge of orange in the terminal joint.

Femora red, tibiae upper half red, lower half and tarsi pale.

Proboscis reaches the second coxae.

Peculiarities typical of Instar V.

9. THE ENEMIES OF CAPSIDS.

We gave very little attention to this side of the subject but we never found any insect attacking capsids. We found a cimicid *Anthocoris sylvestris* sucking the dead bodies of capsids at various stages and we also saw several species of capsid sucking the dead body of the same or different species. It is possible that *Anthocoris sylvestris* and also some species of capsids, e.g. *Psallus ambiguus*, are capable of killing live capsids, but we have never observed them doing so.

The young capsids are so active except at moulting that they would probably escape from such enemies as those which attack aphis. We found dead capsids on the trees and on healthy shoots in cages but we were unable to assign a causal organism.

10. THE FOOD OF APPLE-DWELLING CAPSIDS.

Both the nymphs and adults of *Plesiocoris rugicollis* live mainly on the juices of the leaves, stem and fruit of various species of plants, but they have been seen sucking dead individuals of the same or another species. Where they suck another bug a blackish mark is formed. This is also true of *Psallus ambiguus, Orthotylus marginalis, Atractotomus mali* and larvae of *Phytocoris ulmi*. *Atractotomus mali* has been recorded as attacking caterpillars of Hyponomeuta (13, 20), and in one case we found a large number of adults near a nest of these caterpillars. Such large numbers were never found together in any other place.

Psallus ambiguus feeds on plant juices but it can live for several weeks on dried twigs on which nymphs and adults of *Psylla mali* and young forms of *Tetranychus* sp. were present. No definite observations were made as to its carnivorous nature, but Rymer Roberts writes that "a nymph of *Psallus ambiguus* fed on *Aphis avenae* and also on two syrphid eggs."

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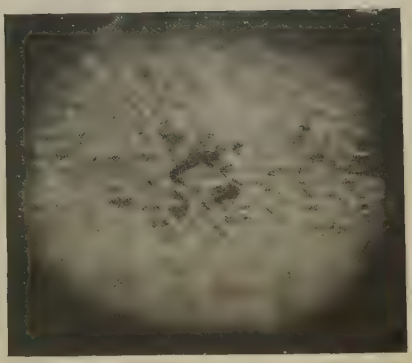

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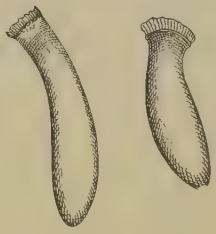

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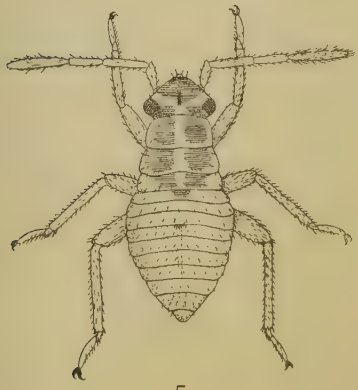

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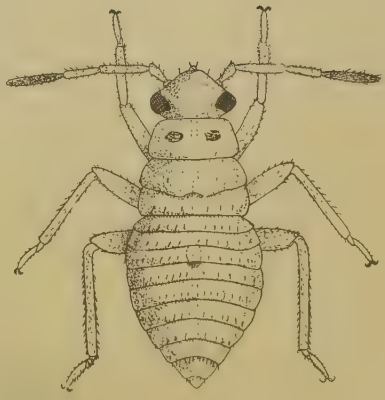

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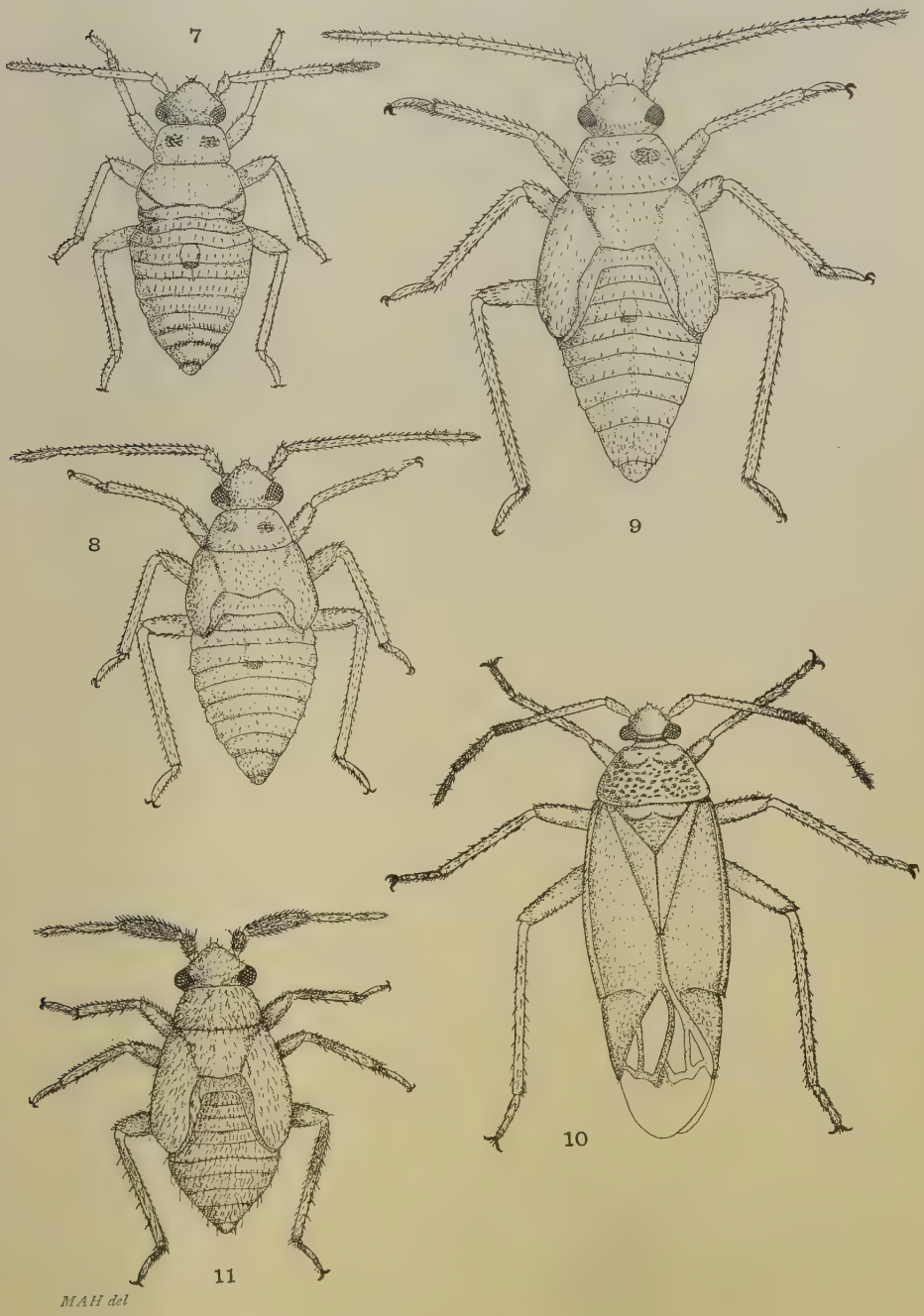
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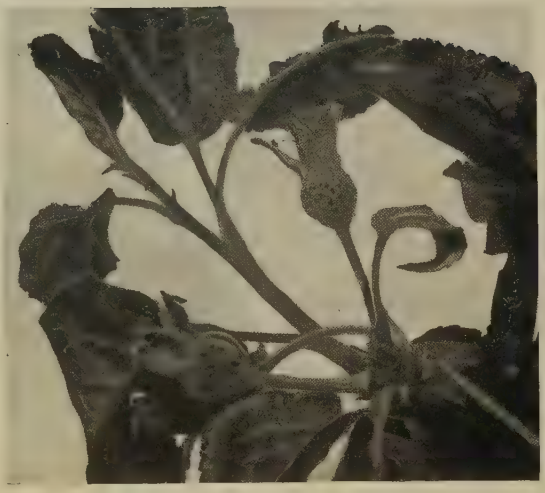

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EXPLANATION OF PLATES.

PLATE IX.

Fig. 1. Egg of *Plesiocoris rugicollis* in situ.
Fig. 2. Surface view of the cap of an egg of *Plesiocoris rugicollis* in situ.
Fig. 3. Eggs of *Plesiocoris rugicollis* in situ.
Fig. 4. A. Egg of *Plesiocoris rugicollis*.
B. Egg of *Orthotylus marginalis*.
Fig. 5. *Plesiocoris rugicollis*, Instar I.
Fig. 6. „ „ „ II.

PLATE X.

Fig. 7. *Plesiocoris rugicollis*, Instar III.
Fig. 8. „ „ „ IV.
Fig. 9. „ „ „ V.
Fig. 10. „ „ Adult.
Fig. 11. *Atractotomus mali*, Instar V.

PLATE XI.

Fig. 12. Apple leaves marked by *Plesiocoris rugicollis*.
Fig. 13. Young apples marked by *Plesiocoris rugicollis*.
Fig. 14. Two apple trees (variety Grenadier).
A. Sprayed and showing normal growth.
B. Unsprayed and showing a severe check to the growth of the leaves due to *Plesiocoris rugicollis*.

NOTES ON THE STRAWBERRY LEAF BEETLE (*GALERUCELLA TENELLA* LINN.).

By H. C. EFFLATOUN, F.E.S., M.R.A.C.

(With 3 Text-figures.)

Specimens of the larvae of this strawberry beetle, received by Mr F. V. Theobald were given to me to describe and follow out the life-history. The following are some notes I have made in regard to the various stages. It is hoped that, later, fuller details of the bionomics of this insect will be ready for publication. The insects bred in the laboratory of the South Eastern Agricultural College were sent to Prof. Theobald from County Monaghan, Ireland, where they had done much damage.

LARVA.

Length, one-eighth to one-sixth inch. Colour, dirty greenish yellow, head black. All the segments of the body, with the exception of the head, pronotum and anal segment, have a pair of elongate, transverse, thickish stripes, the cephalad stripe being larger than the caudad one. The stripes on the meso- and metanota are separated as shown in the figure. The dorsal segments are transversely furrowed. Each segment of the body, with the exception of the thoracic region (pro-, meso- and metanota) have four shining black tubercles on each side. These tubercles vary in size, the largest being near the transverse stripes. The pronotum is free from markings or tubercles and is uniformly dark brownish-grey. The meso- and metanota have two tubercles instead of four on each side; the inner pair are somewhat round, while the outer pair are much larger and somewhat crescent-shaped. The terminal segment is brownish-grey and more hairy than the rest of the body. There are three pairs of true (segmented) legs, which are black, on the three first segments of the body. Each bears two sharp claws. The anal segment possesses a large and simple process or proleg by means of which the larva progresses after the manner of one of the Geometridae. The body is covered with more or less numerous yellow hairs.

PUPA.

About one-tenth inch in length: dark yellowish-brown and slightly hairy. There are fourteen black spines on the dorsum of the cephalic region, each spine arising from a dark papilla, and eight smaller spines on the thoracic region.

The abdominal region has seven distinct segments, the first six of which carry a pair of large, black and shiny tubercles, a pair of small spines in the centre, and another pair of slightly larger spines on the sides. The lateral spines on the sixth segment are stouter and larger than the others. The antennae, instead of curling down between the legs, on the ventral side, extend outwardly and are curved round the back of the legs.

IMAGO.

Length, one-ninth to one-seventh inch. The colour varies slightly from dull yellow to pale brownish. The head has a broad black stripe across it and the head itself is yellow. The third joint of the antennae is longer in proportion than the second. The thorax has a small, more or less round depression on each side and is yellowish in colour with a dark furrow in the centre. The tubercles on the forehead are distinct and shiny. The punctures of the elytra are not deep but present a granulated and shiny appearance. The suture and margin of the elytra are yellow and the shoulders are dark. The ♂ has the fifth segment (ventral) of the abdomen slightly impressed at the apex, the same segment being almost entire in the ♀. The legs are pale; the antennae yellowish and dark at the apex. "The series in the British Museum shows some variation with regard to markings" (1) and "occasionally the elytra are marked with a more or less dark band" (2).

NATURE OF DAMAGE.

Both the larva and the imago damage the leaves of strawberries in exactly the same way. They eat the lower and upper epidermis and the soft underlying tissue, leaving the opposite layer of epidermis intact. The leaves then present a curious and characteristic spotted appearance. If the leaves are left exposed to weathering conditions they may then present a different appearance; they will appear as if regular holes had been eaten out of them and thus errors may arise when trying to identify the insect related to the damage.

The larvae from which the adults were bred were fully mature so that no observations were made as regards their habits, moults, etc.; pupation

began the day following their arrival and this took place underground without the formation of a cocoon.

Date of pupation: June 21st–24th.

Adults hatched: July 22nd to 26th.

The beetles, on hatching, were in a fairly active condition but it took them from three to six days to harden. At the least sound or noise the beetles feigned death and dropped to the ground where they soon burrowed and disappeared out of sight. They were hardly ever observed to feed in the daytime. They fed mostly during the nights and early mornings, when quite a few did not seem to be disturbed, either by noise or even by handling their pot-plant.

This is not the first time that the species has been reported as injurious to the strawberry plant. Ormerod(3) received information of damage done by it from Hundred Acres, Wickham, Hampshire, with a note that they were destroying the strawberry plants in that neighbourhood, and that it was considered a new pest in the locality. Mr Theobald has received it this year from Buckinghamshire also.

Lampa(4) records it from Sweden.

Sacharov(5) records it for the first time in Russia as injurious to strawberries. "The beetle winters," he says, "underneath old leaves on the beds of strawberries; with the arrival of warm weather the insects appear and feed on the young leaves, and oviposit during April and May. The eggs are deposited by the female in a hole gnawed by it in the leaf, 3–10 eggs being laid in such a hole. The egg-stage lasts 12–14 days."

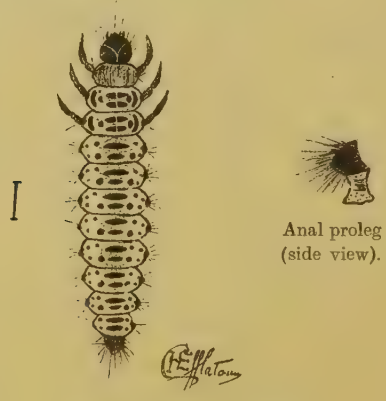
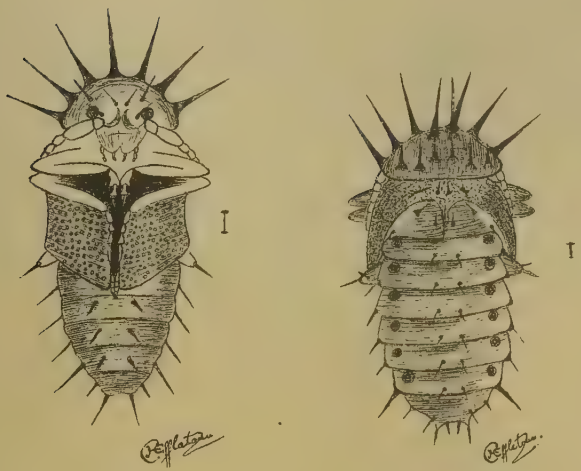


Fig. 1. Larva of *G. tenella*.



Ventral view. Dorsal view.

Fig. 2. Pupa of *G. tenella* Linn.

Fig. 3. Upper surface of leaf damaged by *G. tenella*.

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South Eastern Agricultural College,
Wye, Kent.

October 1*st*, 1917.

OBSERVATIONS ON *PIMPLA POMORUM* RATZ., A PARASITE OF THE APPLE BLOSSOM WEEVIL (INCLUDING A DESCRIPTION OF THE MALE BY CLAUDE MORLEY, F.Z.S.).

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(With Plate XII and 5 Text-figures.)

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1. INTRODUCTORY REMARKS.

Towards the end of May, 1916, I received several consignments of apple blossom buds attacked by *Anthonomus pomorum*. These were kindly sent at my request by Mr J. C. F. Fryer, Entomologist to the Board of Agriculture, who obtained them from an orchard at Chatteris, Cambridgeshire, where the weevil is often abundant. It is a well-known fact that *A. pomorum* is a most difficult pest to control on account of its concealed habits of feeding when in the larval stage, which greatly militates against the effective application of insecticides. The female weevil deposits her eggs in the blossom buds of the apple before they open, and, according to Theobald (1909, p. 106), the young larvae hatch out in from 5–7 days. The blossoms commence to expand but rarely fully open, further growth ceases, and the brown shrivelled petals form a kind of dome-like cap over the receptacle. If one of these so-called "capped

blossoms" be opened the small white apodous larva of the weevil will be found in the centre. In many cases the larva of the weevil will be found to be dead, or weakly, and accompanied by a smaller larva not very unlike it in appearance. This latter larva in most instances will prove to be that of *Pimpla pomorum*, which forms the subject of the present investigation.

During the past year I have carried out a preliminary investigation of the parasites which attack the apple blossom weevil, in the belief that a possible method of control might eventually be afforded by the utilization of these natural agencies. In this connection it is noteworthy that Marchal (1907, p. 15) quotes the experiments of Decaux who was impressed by the multitude of ichneumon flies, or Braconids, which came out of apple buds attacked by *A. pomorum*. Instead of immediately burning these buds as was usually done, Decaux preserved them in boxes covered with gauze, raising the latter from time to time to allow of the escape of the parasites. In 1880 he put this method into use and collected in Picardy five hectolitres of buds from 800 apple trees. By this means, it is stated, that more than a million Anthonomi were destroyed and about 250,000 parasites liberated which, in the following year, were valuable aids in the destruction of the weevils. The orchards treated were surrounded by cultivated fields and consequently isolated from neighbouring fruit plantations. It sufficed to repeat the same operation during the following year, in order to prevent serious damage from the weevil during the succeeding ten years, so thoroughly had the parasites done their work.

The results obtained during one year's preliminary investigation confirmed my surmise that the apple blossom weevil is, in certain localities, at any rate, in this country, equally heavily parasitised. Owing to the great difficulties in obtaining labour entailed by the War, it has not been found possible to prosecute these investigations any further at present, as very considerable quantities of affected blossoms are needed from various parts of the country. Nevertheless, the facts already observed are, I think, of sufficient importance to merit publication. I must express my indebtedness to Mr Claude Morley, who examined a pair of the adult ichneumons submitted to him and identified them as belonging to the species *Pimpla pomorum* Ratz.

2. THE FEMALE.

This species was first described by Ratzeberg (1848, p. 96) from females bred by Reissig from *Anthonomus pomorum* in pear blossom

which is an infrequent host plant for the latter. Subsequently both sexes were reared from the same weevil by Nordlinger, and Ratzeberg later adds (1852, p. 103) that Reissig bred both sexes from apple blossom. In 1912, Catoni recorded having reared considerable numbers in the Trentino.

As adequate descriptions of this sex are given by Schmiedenknecht (1906, p. 1084) and Morley (*loc. cit.* p. 76), it is neither desirable nor necessary to add anything further so far as the female is concerned.

Morley states that examples of this sex are one of the commonest of all Ichneumonidae in Britain in the early spring. There are, however, very few records apparently due to the fact that the insect was not recognised as being a British insect until 1889 when Bridgman established its identity. Up to the present, it is known from certain of the southern and south-eastern counties, but further collecting and observation will doubtlessly reveal its distribution to be more widely spread.

3. THE MALE.

Although the female is an abundant insect very little has been known concerning the male. Ratzeberg surmised that an example bred by Nordlinger, along with females of this species, probably belonged to it; similar males and females were afterwards reared by Reissig. In 1912 Catoni reared a number of males from the *Anthonomus* in Italy but apparently was unaware of their seeming rarity. I know of no further records concerning this sex. Ratzeberg's description is very brief and inadequate but, since it was the only information available, is copied by Schmiedenknecht (1906, p. 1085) and Morley (1908, p. 77). During the course of the present investigation I have bred out a considerable number of examples of this sex and as the result I am able to include herewith a full description thereof which has been drawn up and forwarded to me by Mr Claude Morley.

Description of the Male of *Pimpla* (*Epiurus*) *pomorum* Ratz., by Claude Morley, F.Z.S., etc.

Head with the face and short cheeks immaculate black; mandibles and palpi pure white. Antennae filiform and not apically attenuate, nigrescent testaceous and about half the length of body, pale beneath with the scape and pedicellus pure white below. Thorax with short white humeral callosities before radices, but the collar not in this instance (as is stated by Ratzeberg) pale; metanotal areae wanting, at most the basal indicated; metathoracic apex impressed before a longitudinal carina on either side; spiracles circular. Abdomen linear and not very strongly

punctate; basal segment distinctly punctate laterally; third segment distinctly a little longer than broad (as in *P. ulicicida*, Morl.; *Entom.* 1911, p. 161, ♂ ♀ and herein my character for their distinction given at *Revis. Ichn. Brit. Mus.* III. 1914, p. 82, fails in the ♂ sex); the deeply impressed thyridii, and the third to fifth segments especially basally, pale castaneous; the sixth to eighth narrowly whitish apically; valvulae inconspicuous. Anterior legs and hind trochanters white, with onyches and onychii of the intermediate tarsi nigrescent; front femora entire and not emarginate beneath; hind coxae and femora pale testaceous; hind tibiae white, with apical third and a band before base connected by an internal striga nigrescent; pulvilli large, but shorter than claws; calcaria and basal third of metatarsus white. Wings with the radix and tegulae white, stigma pale luteous; basal nervure continuous through median; areolet nearly twice as broad as long, emitting the oblique second recurrent nervure from very near its apex; nervelet obsolete; nervellus hardly geniculate and intercepted by the weak spurious nervure at its lower third or fourth.

This male has hitherto been mixed in Britain with that of *P. punctiventris* Thoms. which name is inserted *in errore* at *Ichn. Brit.* III. 1908, p. 81.

In the above description Morley describes the scape and pedicellus of the antennae as being pure white below. From an examination of eight examples these joints were seen to be stramineous in every case, so possibly there is some variation in this respect. As the sexual differences are very marked in this species I append below an enumeration of the most characteristic features afforded by a comparison of a number of male and female examples.

Male	Female
Scape of antennae stramineous ventrally	Scape of antennae fuscous ventrally
Thorax black	Mesothorax, the greater part of the pleurae, and a pair of apical spots on the mesothorax, red
Abdomen minutely punctate, testaceous or infuscate	Abdomen coarsely punctate, dark brown or almost piceous
First abdominal segment oblong	First abdominal segment not longer than apically broad

4. OBSERVATIONS ON THE BIOLOGY OF THE SPECIES.

The larva of this Ichneumon lives entirely external to its host, which may be either in the larval or pupal stage of development. Whether it is the larva or pupa that is destined to furnish the food-supply of the

Pimpla, depends upon the time of oviposition by the latter. The earliest hatched larvae meet with larval weevils only, but the later examples will, more often than not, find the host in the pupal condition. Whichever occurs the life of the parasite is the same. Its young larva is usually to be found on the dorsal side of the host larva, with the mouth-parts immersed within the tissues of the latter. The position occupied by the parasite is not constant since the latter was found attached to its host in the following situations: to the fourth tergum; between the eleventh and twelfth terga; to the eighth tergum; between the third and fourth terga; to the second tergum; to the sixth tergum and, in one instance, between the twelfth and thirteenth sterna.

If it be the pupa that is attacked, the parasite was invariably observed to select the anal extremity of the latter. Half-devoured pupae were often met with, the abdomen being largely shrunken away, though the remaining portion of the host appeared to be quite fresh, and exhibited no signs of discoloration or putrefaction. Under these circumstances, it appears not unlikely that the parasitic larva may inject some kind of secretion into the tissues of its host, serving as an antiseptic arresting decomposition.

Only a single parasite was found in relation to each individual host, and a good deal of overlapping of the development stages was found to occur—a feature which is far from rare among hymenopterous parasites. Thus, on May 25th, I found *Pimpla* larvae 2 mm. long, half and fully grown larvae, larvae commencing to spin their cocoons, and fully formed pupae from among less than fifty examples of the *Anthonomus*.

When fully fed, the larva spinsa slight silken cocoon, which is ovoid in shape, measuring on an average 6 mm. long and 2 mm. in diameter (Text-fig. 5). The cocoon can be readily detected within the cavity of the affected apple bud; the silk of which it is composed is white, or, in some instances, the outer fibres thereof are pale brown in colour. When examined under a low power objective, the fibres can be readily observed to be arranged for the most part in a circular manner around girth of the cocoon. The whole structure, and the interstices between the threads, is varnished over with a very thin and transparent layer of glutinous secretion.

Under laboratory conditions, the first example issued on June 17th, 1916, and was a male, the actual time being twenty-three days from the date of commencement of spinning the cocoon. From the above date onwards, until July 5th, a large number of the parasites emerged, the first female appearing on June 21st.

It is noteworthy that all of some eighty unparasitised examples of the host weevil, reared during this investigation, emerged from the pupa prior to the appearance of the *Pimpla*, none issuing later than June 13th.

After the emergence of the perfect insects, the subsequent life of the species is a mystery. It is perfectly clear that there is no available supply of the larvae or pupae of the weevil until the following year. It appears improbable that the adult parasite awaits a period of about ten months for the reappearance of its larval host. Most probably it utilises an alternative species, and passes through a second annual generation, though what that host is likely to be is hard to predict.

A further point of interest is the fact that the parasite occurs in districts where *Anthonomus pomorum* is unknown. For example in Suffolk, according to Morley (1908, p. 77), this weevil is absent, nevertheless the parasite is a common insect in that county, and may be frequently beaten out of Coniferae. Nothing, however, is known regarding the host which it utilises on such occasions.

In this connection some clue may possibly be afforded if we take into account the various hosts utilised by other species of the genus *Pimpla*. There is no doubt whatever that Lepidoptera are usually selected and, out of the forty British species of *Pimpla*, which are enumerated by Morley (1908, pp. 51–118), the vast majority have been bred from various members of this order of insects. The most usually parasitised species are *Retinia buoliana*, *R. resinana*, *Tortrix viridana*, *Orgyia antiqua*, *Odonestis potatoria* and *Clisiocampa neustria*. Many other species, however, serve as hosts and great variation is exhibited in the size of the host selected. Thus *Pimpla rufata* Gmeb. has been bred from *Tortrix viridana* and the relatively gigantic *Sphinx ligustri*; and *P. instigator* Fab. from *Psyche viciella* and *Smerinthus populi*! Outside the order Lepidoptera there are few reliable records; four British species of *Pimpla* have been bred from the egg masses of spiders and about six species have been reared from Coleoptera, almost exclusively Curculionidae. With the exception of *Pimpla pomorum* these latter species have been reared from Lepidopterous hosts also. Of the species known to parasitise *Anthonomus pomorum* the following host records are enumerated by Morley (1908, pp. 60, 81, and 99). *Pimpla graminellae* has been reared from *Odonestis potatoria*, *Epippiphora scutulana* (or *E. pflugiana*) and *Clostera reclusa*. *Pimpla sagax* has been reared from *Retinia buoliana*, *R. resinana*, *R. turionana*, *Coccyx cosmophorana*, *Tischeria complanella*, *Conchylis posterana*, and *Lithocolletis trifasciella*. Morley (*loc. cit.* p. 81) also records an example bred on April 26th from dried heads of *Centaurea nigra* gathered beneath

fir trees. He suggests the gall-forming Trypetid *Urophora solstitialis* as its host, "unless of course its presence there was purely accidental and its true association were with the overhanging conifers, in which case it would surely have shown itself in the jar in the course of the preceding month." In my opinion it is more probable that one or other of the several species of Lepidopterous larvae which inhabit the flower heads of *Centaurea* is the host in question. *Pimpla examinator* Fab. has been bred from *Retinia buoliana*, *Liparis chrysorrhoea*, and many other Lepidoptera. *Pimpla pomorum* is exceptional in that it has only been bred with certainty from *Anthonomus pomorum*. From analogy with other species of its genus it is probable that it utilises Lepidopterous hosts also, although it is remarkable that it has not so far been reared therefrom. Morley states that he has invariably beaten it from *Pinus sylvestris* and *Picea excelsa* in fir woods about Bentley in Suffolk. This suggests that *Retinia buoliana* or other pine infesting Tortricid may prove to be one of its hosts. In the absence of pine trees (as in the Chatteris locality, Cambridgeshire) certain of the commoner Lepidopterous larvae feeding on apple, hawthorn and other plants, may not unlikely prove to be parasitised by this species.

As a general rule the parasites of exposed hosts—in other words host insects not sheltered by a cocoon, or in a bud, leaf or stem—live internally. Howard has remarked (1913, p. 161) that it is very rare to find an external Hymenopterous parasite on an unprotected host insect, and it occasionally happens that the same species of parasite, in its larval stage, will feed exteriorly upon a protected host and interiorly upon an unprotected host. So little is known concerning the biology of the genus *Pimpla* that it is impossible to assert how far the ecto- and endoparasitic habits prevail, as both protected and exposed hosts may be utilised by one and the same species. A thorough investigation of the economy of members of this genus is likely to yield results of considerable biological interest and importance.

5. THE YOUNG LARVA.

The smallest larva met with measured 1·1 mm. long (Plate XII, fig. 1) and, although I have had no opportunity of examining the newly hatched individual, I have little doubt that it does not differ from the latter in any essential details of its morphology. It is pearly white in colour, and differs from the fully grown larva in the following among other features. (1) The relatively large size of the head, which is completely exserted, and incapable of any withdrawal into the first trunk segment. It

measures ·22 mm. long and ·24 mm. broad, the ratio of the length of the head to the total length of the larva being as 1 : 5·4; in the fully grown larva the ratio is 1 : 8·3. The antennae are equal in size to those of the fully grown larva, and are consequently of a much greater relative size. (2) The dorsal curvature of the body is much less pronounced. (3) The labial and maxillary papillae are represented in each case by a group of six or seven minute cuticular structures on either side (Text-fig. 1). (4) The body segments are more rounded and uniform in character, and the dorsal pseudopodia are not yet formed. (5) The tracheal system is incompletely developed, and nine pairs of spiracles are present, the minute vestigial second pair not yet being evident.

Fig. 1. Papillae from the left ventral side of the labium of a young larva: highly magnified.

6. THE FULLY GROWN LARVA.

When fully grown the larvae vary from whitish, or dull cream colour, to pale brownish white or pink, and measure when alive from 4·5 to 5 mm. in length, with an average maximum breadth of 1·25 to 1·5 mm. They are elongate fusiform in shape, narrowing towards the two extremities, and more so at the anal than at the cephalic end. The dorsal surface is more prominently arched than the ventral (Plate XII, fig. 2), and the cuticle is studded with numerous minute conical chitinous papillae. These structures have an average diameter of ·004 mm. and give the cuticle, under a low magnification, the appearance of fine shagreen; those on the dorsal region are slightly larger than elsewhere. A few short setae occur and, for the most part, are grouped in the form of a loose circlet around the middle of each segment. A well-defined head is present followed by thirteen sharply demarcated body segments, which are related to one another in length in the following proportions: 6–7 : 6 : 5–6 : 6 : 7 : 7–8 : 8–9 : 8–9 : 7–8 : 6–7 : 5 : 3–4 : 3. Owing to the variable amount of contraction or extension which the segments undergo, these ratios are not capable of more exact determination. The *head* differs from the remainder of the body in being enclosed in a smooth and slightly thicker chitinous investment; it is, moreover, usually a little darker in colour. It is about as broad as long, measuring ·6 mm. in either direction. On the dorsal aspect, it has two ovoid or somewhat pyriform infuscate markings, which are placed alongside the middle line, parallel with the longitudinal axis. Definite though vestigial *antennae*

are present; they are peg-like in form and measure ·049 mm. long and ·007 mm. wide across the middle region (Text-fig. 2).

The *mandibles* (Text-fig. 3) closely resemble one another. At its base, each is flattened and plate-like and measures ·07 mm. in breadth; apically it is drawn out into a straight spine-like piercing tooth, beset with minute spines along a portion of its antero-posterior margins. The mandible measures, from the apex of the tooth to the condyle, ·11 mm. in length.

Fig. 2. Right antenna of a fully grown larva: highly magnified.

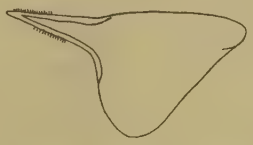

Fig. 3. Right mandible of a fully grown larva. ×300.

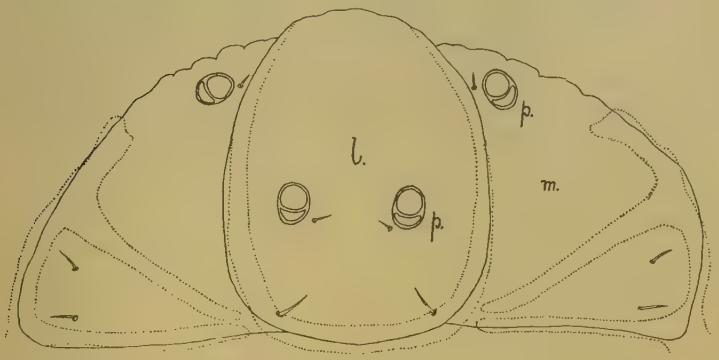

Fig. 4. Ventral view of the labium and 1st maxillae of a fully grown larva; ×600. *l*, labium: *m*, 1st maxilla (left): *p*, sensory (?) papillae. The dotted lines indicate the position of the underlying head skeleton.

The *mouth* is bounded dorsally by the labrum, laterally by the first maxillae, and its floor is formed by the labium. The *labrum* is an oblong transverse plate, slightly curved and measures ·13 mm. from side to side, and ·04 mm. in the antero-posterior direction. The *first maxillae* (Text-fig. 4) are extremely simple and their ventro-lateral margins are closely applied to the sides of the labium. No traces of galeae or laciniae are to be found, neither is there any division into basal sclerites. Near to its outer free margin each maxilla carries a papilla (*p*) arising from a divided basal ring of chitin measuring ·015 × ·011 mm. This structure occupies the same position as the group of small papillae found in the young

larvae. The *labium* (*l*) is ovoid in form and measures ·14 mm. in length and ·10 mm. broad (Text-fig. 4). Its free margin is simple and undivided; a pair of papillae (*p*), similar in form and size to those found in the first maxillae, are also present. These are similarly represented in the young larvae by a pair of groups each comprising seven minute papilla-like structures. From their position and constancy of occurrence, these structures suggest their possibly being the vestigial counterparts of the labial and maxillary palpi, and have been regarded as palpi by Cushman in his description of the larva of *Thesolochus conotracheli* (1916, p. 853 and Fig. 8). The fact that in *Pimpla pomorum*, at any rate, they are represented in the young larvae by groups of minute papillae, militates against this interpretation of their morphology.

The *trunk* segments are separated by deep, well-defined intersegmental grooves, and segments 4 to 10 have the tergal region raised in such a manner as to form a row of transverse mid-dorsal tubercles or pseudopods. These are only slightly developed and are more noticeable from a lateral rather than from a dorsal view (Plate XII, fig. 2). In a similar way, the lateral regions of the same segments are slightly produced outwards to form rounded mamilla-like swellings. Ten pairs of *spiracles* are present, and are situated on the first, second, and fourth to eleventh segments. The first pair is placed on the posterior region of its segment, near the intersegmental groove separating it from the succeeding segment. The second pair of spiracles is vestigial and non-functional. These spiracles are very small and hard to detect; they occupy a position on their segment similar to that of the preceding pair. No spiracles are present on the third segment, while the remaining eight pairs are situated far forwards on their respective segments.

7. COMPARISON WITH LARVAE OF OTHER ICHNEUMONOIDEA.

In the possession of a well-defined head and thirteen body segments the larva of *Pimpla pomorum* conforms to the usual type found among Ichneumonoid larvae. This same number of segments has been found to obtain in a number of species, notably by Xambeu (1898)[1] in *Pimpla oculatoria* Grav., by Seurat (1899) in *P. mexicana*, by Giraud (1863) in *P. detrita* Holmg. (*graminellae* Grav.), by Ratzeberg (1844) in *Exochilium* (*Anomalon*) *circumflexum* L., by Riley (1888) in *Thalessa lunator* Fab., by Berthoumieu (1894) in *Ichneumon rubens* Fons., by Morley (1903) in

[1] Xambeu mentions (p. 239) twelve segments in *P. oculatoria*, the hindmost being "prolongé par un mamelon rétractile"; the latter structure, however, appears to be the reduced thirteenth segment.

Exetastes cinctipes Retz., by Wardle (1914) in *Hypamblys albopictus* Grav., by Cushman (1916) in *Thersolochus conotracheli* Riley, by Klapálek (1889) in the curious larva of *Agriotypus*, by Cushman (1913), and subsequently by Smith (1914) in *Calliephialtes*, and also by Seurat (*loc. cit.*) in the following species: *Mesochorus vittator* Zett., *Anilasta ebenina* Grav. et Thom., *Xylonomus praecatorius* Fab., and *Phymatodes variabile*. Newport (1855) similarly recognised thirteen segments in the larvae of *Paniscus virgatus* Fourc., and *Anthophorabia* (*Mellitobia*) *retusa* Newp., while Graf (1917) figures a similar number in the larva of *Bassus gibbosus* Say. Apparent exceptions to this rule are often difficult to explain, and very possibly in some instances the small thirteenth segment has been overlooked. Thus Timberlake (1912) only recognised twelve segments in the larva of *Limnerium validum* (Cress.) and Morley (1914) mentions a similar number in *Paniscus cephalotes* Holmgr. In *Ichneumon atropos* Curt. Newport (*loc. cit.*) detected fourteen segments, including the anal process, but the latter structure is most probably an outgrowth of the thirteenth segment and this species would therefore conform in possessing the usual number of segments. In *Spilocryptus cimbicis* Tschek. Morley (1907) states there are twelve segments, apparently including the head in his enumeration; in the onisciform larva of *Mesostenus obnoxius* Grav. this same observer (1906) found only nine segments.

In the retention of ten pairs of spiracles the larva of *Pimpla pomorum* exhibits a primitive feature not hitherto recorded, so far as I am aware, in any other species of Ichneumonoidea. Laboulbène (1858) noticed nine pairs of spiracles in the larva of *Pimpla Fairmairii* and the same number has been observed by Giraud in *P. detrita* Holmgr., by Xambeu in *P. oculatoria* Grav., by Ratzeberg (1844) in *Ichneumon pisorius* L., by Berthoumieu in *I. rubens* Fons., and by Seurat in *Pimpla mexicana*, *Anilasta ebenina*, *Xylonomus praecatorius*, *Mesochorus vittator*, and *Phymatodes variabile*. The vestigial second pair of spiracles is very small, being easily passed over, and it is not improbable that, in certain cases, it has been overlooked by previous observers. It is noteworthy that ten pairs of spiracles are also present in the newly hatched larva of the honey bee, but in this species they correspond, according to Nelson (1915), to the second to eleventh segments inclusive.

In the presence of body hairs, and the absence of either a caudate appendage or anal vesicle, the larva of *Pimpla pomorum* exhibits features that are characteristic of Ichneumons leading an ectoparasitic mode of life.

8. THE MALE PUPA.

In describing the pupa, whether male or female, one meets with the very real difficulty of selecting from the few characters which it affords, those which appear to be of diagnostic value. In hardly a single instance do we find a description of an Ichneumonid pupa sufficiently detailed to be of value for comparative purposes. So far as the present species is concerned, I have only dealt with those morphological features which appear likely to prove of generic or specific value. Of these, the characters afforded by the abdominal spines appear to be important.

Fig. 5. Cocoon showing the emergence hole made by the adult Ichneumon. × *circa* 5.

In the *male pupa* (Plate XII, fig. 3) the head is a little wider than the thorax across the widest region, with the frontal surface inclined obliquely downwards. The mouth-parts are wholly ventral in position, with the first maxillae and labium lying parallel with the longitudinal axis of the body, and near to the surface of the prosternal region. The antennae curve over the anterior surface of the head, closely applied to the inner margins of the eyes, and lie for the remainder of their length on the ventral side of the body. Their apices extend backwards as far as the fourth abdominal segment. The extremities of the anterior tarsi reach as far as the apices of the middle tibiae; the second pair of legs are wholly invisible dorsally and their extremities reach to the middle of the second tarsal joint of the hind legs; in the third pair of legs the apices of the tarsi extend slightly further backwards than those of the antennae. The fore-wings completely overlie the hind-wings and exclude them from view; they reach backwards as far as the extremity of the first tarsal joint of the middle legs. Seven segments are evident in the abdomen but the seventh or hindmost segment is of a composite nature and apparently consists of two partially fused pupal segments. The first segment is devoid of spines, while the second to fourth segments are each armed with a single pair of small ventral spines. The fifth segment is provided with four ventral and two dorsal spines; the sixth segment has a circlet of spines of which usually six are ventral in position, four are lateral and

four dorsal. The apical region of the abdomen is prolonged posteriorly into a pair of short appendages, which are imperfectly two-jointed, and rounded at their extremities. On either side of these appendages, is a pair of papillae, each carrying a conspicuous curved spine, considerably longer than the spines on any of the preceding segments; a pair of smaller spines are also present ventrally.

Length 5 mm.; maximum breadth across the thorax 1·5 mm.

9. THE FEMALE PUPA.

The female pupa (Plate XII. fig. 4) differs from the male pupa in that the antennae extend as far backwards as the sixth abdominal segment while the hind legs reach to the seventh segment. The terebra is folded back over the dorsal side of the abdomen, its apex reaching to the middle of the first segment. The latter is unarmed, but the second and third segments are each provided with a pair of small dorsal spines. The fourth segment has four similar dorsal spines and two ventral spines; vestiges of a second and outer pair of ventral are also present. The fifth segment is armed with four dorsal, two ventral and two prominent lateral spines —one on either side. The sixth segment has usually six ventral, four dorsal and large lateral spines. The seventh or apical segment is provided, on either side, with a pair of large curved ventro-lateral spines as in the male, and, furthermore, is prolonged backwards in the form of a pair of unjointed appendages each surmounted by a conspicuous spine.

Length 4·25 mm. to 4·45 mm.; maximum breadth across the thorax 1·5 mm.

10. EFFICIENCY AS A PARASITE.

Between May 25th and 29th, 1916, 1270 apple buds, harbouring the weevil in various stages of development, were separately examined under a binocular microscope. Among these infested buds 349 contained larvae of *Pimpla pomorum*. This gives a ratio of parasitism working out at 27·4 per cent., which is a relatively high one, and remarkably near to that found by Decaux to be efficient in France in the control of the weevil by means of species of Braconidae. A further 605 buds gave inconclusive results, and are not included in this enumeration. Many of them were either attacked by mould or were empty, or contained dead or sickly hosts, without certain indications of being parasitised by the *Pimpla*. The appearances in many cases suggested that the parasite had been present, but had died along with the host. Mould favoured by wet weather, appeared often to kill the latter when parasitised, and the parasitic larva usually died also as the result. When the petals of the

unopened buds were not tightly closed, the mould appeared to gain access more readily.

The effect of the parasitism on the host is complete, the latter dying in every instance whether it be in the larval or pupal stage. It is probable, therefore, that *Pimpla pomorum* is an important natural aid in the control of the apple blossom weevil in this country. The high rate of mortality which I have shown it exacts from its host, together with the general fact of its biology, clearly supports this contention. Measures involving the preservation and increase of the parasite, along lines similar to those conducted in France, are fully worthy of adequate trial as an accessory means of controlling the weevil. The utilisation of natural enemies in the control of injurious insects has led to highly encouraging results in America, Italy, France and elsewhere; nevertheless, it is a method which can only be advocated after a thorough scientific enquiry into the life-economy of each particular species and its parasites. In the case of the apple blossom weevil, among the various measures recommended for dealing with this insect is that of jarring the trees, which causes the affected apple blossoms to fall readily. Frequently, many fall in the natural course of events without the trees being shaken. The blossoms are then collected and burnt. With the expenditure of very little extra time and labour the blossoms, after being collected, might easily be placed in boxes and saved. Shallow well-fitting wooden boxes are best for the purpose, and not more than six layers of blossoms should be placed in a single box, as they rapidly decompose and rot in damp weather. The lids of the boxes should have as large an area as possible replaced by cheese cloth or butter muslin, to allow of the admission of air and light. If, however, the finest holed perforated zinc be used the boxes will then serve their purpose for a much longer period without trouble. All that is necessary is to examine the boxes daily from about the beginning of the second week in June, removing the lids thereof for a few minutes to enable the parasites to fly away once they commence appearing. It is advisable to jar the box sharply before doing so, in order to cause those weevils which may have crawled up the sides to loose their foothold and so prevent their escape. By this means the greater number of the weevils are imprisoned within the boxes and eventually die, while the parasites are liberated to continue their beneficial mission. Experiments were conducted in order to ascertain whether it be possible to utilise gauze of such a mesh which would allow of the liberation of the parasites, and the retention of the beetles, and thus obviate the necessity for the periodical removal of the lids of the boxes. Owing to the relatively

large size of the parasites, compared with the size of the host, it was found that the parasites did not readily issue through a mesh which, at the same time, was small enough to imprison the host weevils. The method of collecting the affected blossoms followed by the burning of the same, is open to a good deal of doubt as to its advisability on account of the large number of beneficial parasites which are destroyed at the same time.

11. REMARKS ON OTHER PARASITES OF *ANTHONOMUS POMORUM*.

A useful summary of hymenopterous parasites recorded from this host is given by Elliott and Morley (1907 and 1911) and further records are quoted by Catoni (1912). Several of the statements, however, are of doubtful value as they probably refer to parasites of Aphids and other insects and have no closer connection with *Anthonomus* than the fact that the host food-plant was apple in each case. Among these doubtful records may be included *Apanteles* (*Microgaster*) *albipennis* Nees, *Bracon variator* Nees, *Asaphes vulgaris* Walk. (*Chrysolampus aeneus* Ratz.), *Encyrtus flavomaculatus* Ratz. and *Pteromalus* (*Habrocytus*) *saxesenii* Ratz. (Thoms.). Brischke, however, has bred *Pimpla examinator* Fab., *P. sagax* Htg., and *Apanteles* (*Microgaster*) *lacteus* Nees from this host. *Apanteles* (*Microgaster*) *impurus* Nees was frequently bred by Reissig from apple blossom infested by the weevil and has also been reared by Catoni. According to Ratzeberg (1848, p. 84), Nordlinger bred a single male of *Campoplex latus* Ratz., and it is stated that Goureau has bred *Pimpla graminellae* Grav. from the same host. Catoni (1912, p. 149) has also bred *Meteorus ictericus* (Nees) and *Habrocytus fasciatus* Thoms.

During this investigation *Pimpla pomorum* was the only parasite which I bred from the *Anthonomus*. Whether or not any of the above species are likely to prove of value from the economic point of view is doubtful. Males of *Pimpla examinator* are common in this country though no certain records of the female appear to be known. *P. sagax* has not often been met with while, according to Morley, there are but few reliable records of *P. graminellae*.

The species of *Apanteles* are well-known natural enemies of Lepidoptera and the extent to which they may parasitise insects of other orders requires fuller investigation before we are able to formulate definite conclusions with regard to their economic significance.

12. SUMMARY OF GENERAL CONCLUSIONS.

1. *Pimpla pomorum* Ratz., in its larval stage, is an ecto-parasite of the Apple Blossom Weevil (*Anthonomus pomorum*) attacking both larvae and pupae of the latter.

2. The larva of this Ichneumon is composed of a definite head and thirteen trunk segments; no caudal process or anal vesicle is present. Ten pairs of spiracles are evident but the pair situated on the second segment is minute and vestigial.

3. Pupation takes place within a slight silken cocoon spun within the cavity of the unopened apple buds. The adult Ichneumons commenced to emerge on June 17th, and an average of twenty-three days was occupied from the time of spinning the cocoon.

4. The male insect was met with in considerable numbers for the first time, and its identity made certain. Hitherto nothing has been known of this sex beyond Ratzeberg's surmise that a male *Pimpla* bred by Nordlinger belongs to this species and that Catoni has reared it in Italy. A full description of the male by Mr Claude Morley is included in the present paper.

5. After emergence in June, the biology of this species during the rest of the year is unknown. Most probably it passes through a second generation and utilises certain species of Lepidoptera as hosts. In localities where *Anthonomus pomorum* is unknown both generations probably parasitise Lepidoptera.

6. From among 1270 apple buds gathered at Chatteris in Cambridgeshire, and infested by the Apple Blossom Weevil, *Pimpla pomorum* was found to effectively parasitise the latter to the extent of 27 per cent. This ratio of parasitism is relatively high, and agrees very closely with that found by Decaux to obtain among Braconid parasites of the same host.

7. It is suggested that measures involving the preservation and increase of this parasite, along lines similar to those conducted in France, should be given an adequate trial; it is likely that they may prove of value as an accessory means of controlling the weevil.

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Fig. 1

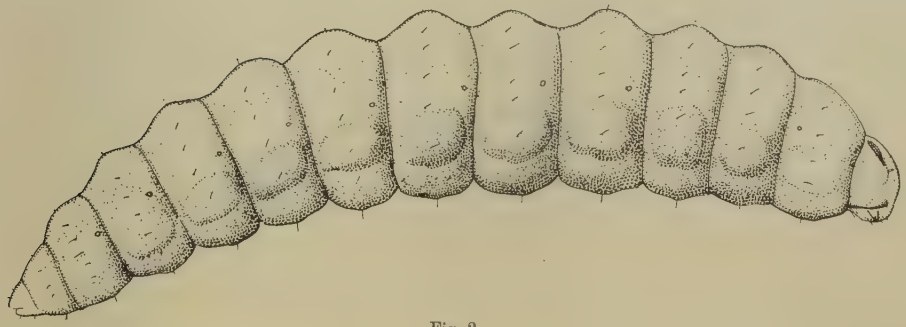

Fig. 2

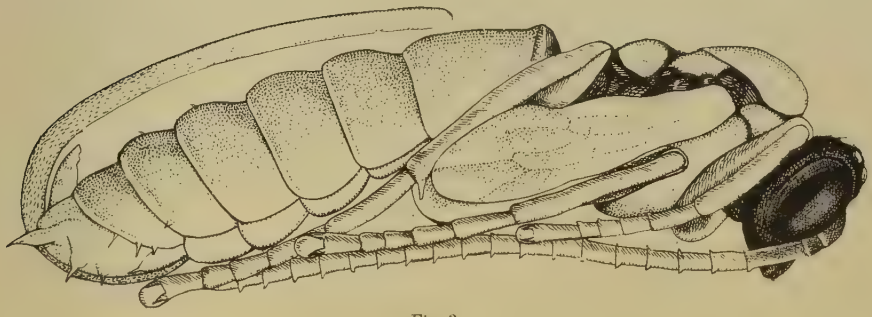

Fig. 3

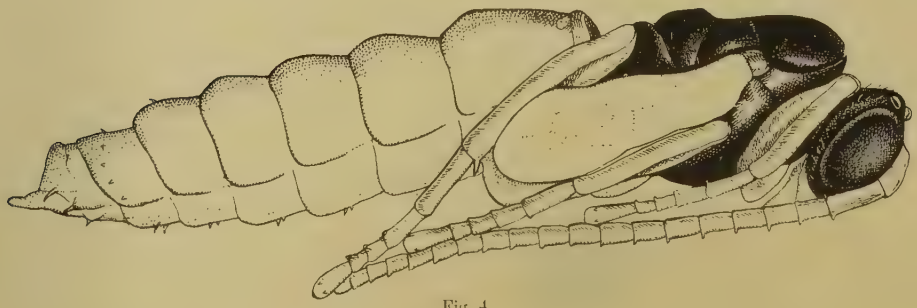

Fig. 4

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EXPLANATION OF PLATE XII.

Fig. 1. Young larva of *Pimpla pomorum* seen from the right side. ×62.

Fig. 2. Fully grown larva seen from the right side. ×26.

Fig. 3. Female pupa, lateral view. ×26.

Fig. 4. Male pupa, lateral view. ×26.

A LIST OF COCCIDAE AFFECTING VARIOUS GENERA OF PLANTS.

By E. ERNEST GREEN, F.E.S., F.Z.S.

(*Continued from page* 89)

DACRYDIUM (Coniferae).
- Ctenochiton dacrydii.

DACTYLIS (Gramineae).
- Pseudococcus walkeri.
- Ceroputo volynicus.
- Luzulaspis luzulae.

DAHLIA (Compositae).
- Pseudococcus affinis.
- Pulvinaria psidii.

DALBERGIA (Leguminosae).
- Monophlebus dalbergiae, octocaudata.
- Tachardia lacca.
- Lecanium expansum.
- Aspidiotus trilobitiformis, lataniae, simillimus, transparens.

DALEA (Leguminosae).
- Ceroplastodes daleae.

DAMMARA (Coniferae).
- Pseudococcus aurilanatus.

DANAE (Liliaceae).
- Fiorinia pellucida.

DANTHONIA (Gramineae).
- Eriococcus danthoniae.

DAPHNE (Thymeliaceae).
- Rhizococcus gnidii.
- Pseudococcus similans.
- Lecanium magnoliarum.
- Aspidiotus caldesii, hederae, camelliae, lataniae.

DASYLIRION (Bromeliaceae).
- Lecaniodiaspis yuccae.
- Pseudococcus dasylirii.

DATURA (Solanaceae).
- Pseudococcus virgatus.
- Aspidiotus hederae.

DAVALLIA (Filices).
- Hemichionaspis aspidistrae.
- Lepidosaphes ocellata.

DAVIESIA (Leguminosae).
- Pulvinaria tecta.
- Asterolecanium stypheliae.
- Chionaspis nitida.
- Poliaspis nitens.
- Aspidiotus hederae.
- Lepidosaphes casuarinae.

DEBREGAESIA (Urticaceae).
- Pseudococcus debregaesiae.
- Ceroplastes ceriferus.
- Hemichionaspis mussaendae, minor.

DENDROBIUM (Orchidaceae).
- Leucaspis stricta.
- Aspidiotus dictyospermi.
- Lepidosaphes cocculi.

DENDROCALAMUS (Gramineae).
- Asterolecanium bambusae, coronatum.
- Antonina bambusae.
- Chionaspis angusta.

DENDROPHTHORA (Loranthaceae).
- Pulvinaria dendrophthorae.

DERRIS (Leguminosae).
- Lepidosaphes dilatilobis.

DESCHAMPSIA (Gramineae).
- Eriopeltis festucae.

DESMANTHUS (Leguminosae).
- Ceronema africana.

DEUTZIA (Philadelphaceae).
- Aspidiotus perniciosus.

DEVERRA (Umbelliferae).
- Chionaspis bilobis.

DIANELLA (Liliaceae).
Leucaspis cockerelli.
Parlatoria proteus.
DICHAPETALUM (Chailletiaceae).
Aspidiotus maeandrius.
DICHOPSIS (Sapotaceae).
Iceryae seychellarum.
Vinsonia stellifera.
DICTYOSPERMA (Palmaceae).
Pinnaspis buxi.
Aspidiotus dictyospermi, articulatus, ficus.
DIELYTRA (Fumariaceae).
Lecanium hesperidum.
DILLENIA (Dilleniaceae).
Lecanium cocophyllae.
DILLWYNIA (Leguminosae).
Lecanium pingue.
Pulvinaria contexta.
Poliaspis exocarpi.
DIOON (Cycadaceae).
Poliaspis cycadis.
Diaspis zamiae.
DIOSCOREA (Dioscoreaceae).
Aspidiotus hartii, destructor, transparens.
DIOSMA (Rutaceae).
Lecanium oleae.
Aspidiotus camelliae.
DIOSPYROS (Ebenaceae).
Icerya seychellarum.
Lecaniodiaspis tessellata.
Phenacoccus pergandei.
Ceroplastes ciripediformis.
Pulvinaria citricola.
Lecanium corni, bicruciatum.
Diaspis pentagona.
Aspidiotus perniciosus, dictyospermi, duplex, aurantii, orientalis.
Parlatoria pergandei-phyllanthi.
DIPTEROCARPUS (Dipterocarpaceae).
Tachardia lacca.
DIRCA (Thymeliaceae).
Chionaspis lintneri.
DISPORUM (Liliaceae).
Aspidiotus hederae.
DISTICHLIS (Gramineae).
Sphaerococcus distichlium.
Eriococcus salinus.
DISTYLIUM (Hamamelideae).
Chionaspis latissima.
DOBERA (Salvadoraceae).
Dinaspis reticulata.
DODONAEA (Sapindaceae).
Walkeriana senex.
Pulvinaria dodonaeae, thompsoni, psidii.
DOLICHOS (Leguminosae).
Ceroplastodes cajani.
Inglisia bivalvata.
Lecanium longulum.
DOMBEYA (Sterculiaceae).
Icerya jacobsoni.
DOODIA (Filices).
Alecanopsis filicum.
DORYCNIUM (Leguminosae).
Asterolecanium fimbriatum.
DOVYALIS (Flacourtiaceae).
Howardia biclavis.
Cerococcus ornatus.
DRABA (Cruciferae).
Asterolecanium fimbriatum.
DRACAENA (Liliaceae).
Lecanium hesperidum.
Hemichionaspis dracaenae, aspidistrae.
Pinnaspis buxi.
Chionaspis tangana.
Aspidiotus lauretorum, tinerfensis, dictyospermi, lataniae, hederae.
Leucaspis cockerelli.
DRIMYS (Magnoliaceae).
Inglisia patella.
Pseudoparlatoria parlatorioides.
Lepidosaphes drimydis.
DRYANDRA (Proteaceae).
Ceronema dryandrae.
Aspidiotus dryandrae.
Parlatoria dryandrae.
DRYMUS.
Aspidiotus moreirae, pisai.
DRYPETES (Euphorbiaceae).
Lecanium hemisphaericum.
DURANTA (Verbenaceae).
Pulvinaria psidii.
Lecanium oleae.
Orthezia insignis.
DURIO (Malvaceae).
Chionaspis durionis.
DYSOXYLON (Meliaceae).
Chionaspis dysoxyli.

DYSOXYLON (Meliaceae)—*cont.*
Aspidiotus dysoxyli.
Lepidosaphes pyriformis.

EARINA (Orchidaceae).
Ctenochiton elongatus.
ECHINOCACTUS (Cactaceae).
Diaspis echinocacti.
ECHITES (Apocynaceae).
Phenacoccus mangiferae.
Aspidiotus trilobitiformis.
EDGEWORTHIA (Thymeliaceae).
Pseudococcus edgeworthiae.
EHRETIA (Boragineae).
Aspidiotus replicatus.
ELAEAGNUS (Elaeagnaceae).
Lecanium bicruciatum, persicae, hesperidum, nigrofasciatum.
Ceroplastes floridensis.
Chionaspis difficilis, elaeagni, vitis.
Diaspis crawii.
Aspidiotus camelliae, britannicus, rossi.
Aonidia elaeagni.
Lepidosaphes citricola, crawii, ulmi.
ELAEIS (Palmaceae).
Ceroplastes actiniformis.
Hemichionaspis marchali.
Aspidiotus elaeidis.
Ischnaspis filiformis.
ELAEOCARPUS (Tiliaceae).
Eriococcus pallidus.
Pseudococcus scrobicularum.
Lecanium formicarii.
Eriochiton spinosus.
Ctenochiton elaeocarpi, flavus.
Inglisia ornata.
Hemichionaspis scrobicularum.
ELAEODENDRON (Celastraceae).
Fiorinia elaeodendri, plana.
ELAPHRIUM (Burseraceae).
Ceroplastes ceriferus.
ELLIPANTHUS (Connaraceae).
Chionaspis vitis.
ELYMUS (Gramineae).
Ripersia smithii.
ELYTROPAPPUS (Compositae).
Sphaerococcus africanus.
Pseudococcus elizabethae.

EPACRIS (Epacridaceae).
Eriococcus multispinosus-laevigatus.
Lecaniodiaspis microcribraria.
EPHEDRA (Gnetaceae).
Pseudococcus ephedrae.
Lichtensia ephedrae.
Philephedra ephedrae.
Stotzia striata.
Filippia ephedrae.
Dinaspis ichesii.
Leucaspis ephedrae.
Aspidiotus trabuti, ephedrarum.
Parlatoria ephedrae.
EPIDENDRUM (Orchidaceae).
Asterolecanium epidendri.
EPIGAEA (Ericaceae).
Aspidiotus epigaeae.
ERANTHEMUM (Acanthaceae).
Icerya seychellarum, sulfurea.
Lecanium hemisphaericum, depressum.
Pulvinaria jacksoni.
EREMOPHILA (Myoporaceae).
Aspidiotus coralinus, hederae.
ERICA (Ericaceae).
Orthezia maenariensis, urticae.
Asterolecanium fimbriatum.
Eriococcus devoniensis, ericae.
Ripersia halophila.
Pseudococcus ericicola.
Pulvinaria ericae.
Lecanium oleae, hemisphaericum.
Diaspis ericicola.
Chionaspis salicis.
Adiscodiaspis ericicola.
Aspidiotus hederae, bavaricus.
Lepidosaphes ulmi.
ERIGERON (Compositae).
Pseudococcus neomexicanus.
Ceroplastes cultus, cuneatus.
ERIOBOTRYA (Rosaceae).
Icerya purchasi.
Ceroplastes vinsonii.
Diaspis pentagona.
Aspidiotus dictyospermi, aurantii.
Parlatoria oleae, pergandei.
ERIODENDRON (Malvaceae), 'Silk Cotton.'
Aspidoproctus giganteus.
Lecanium intimum, nigrum.

ERIODENDRON (Malvaceae)—*cont.*
ASPIDIOTUS pedroniformis.
ERIODICTYON (Hydrophyllaceae).
PSEUDOCOCCUS yerba-santae.
ERIOGONUM (Polygonaceae).
ERIOCOCCUS palmeri, eriogoni.
PSEUDOCOCCUS maritimus.
ERIUM eriogoni.
ERYTHEA (Palmaceae).
COMSTOCKIELLA sabalis.
HEMICHIONASPIS aspidistrae.
ERYTHRASPIS.
ASPIDIOTUS camelliae, erythraspidis.
ERYTHRINA (Leguminosae).
PSEUDOCOCCUS crotonis.
LECANIUM tenebricophilum, oleae.
PULVINARIA maxima.
ERIOCHITON theae.
DIASPIS pentagona.
ASPIDIOTUS dictyospermi, pustulans.
LEPIDOSAPHES erythrinae.
ERYTHROPALUM (Olacaceae).
LECANIUM cocculi.
EUCALYPTUS (Myrtaceae).
MONOPHLEBUS fortis, crawfordi, crawfordi-levis, crawfordi-pilosior.
GUERINIELLA serratulae.
CALLIPAPPUS australis, immanis.
APIOMORPHA attenuata, bauerleni, calycina, conica, duplex, minor, ellipsoides, floralis, helmsii, karschi, maliformis, munita, munita-tricornis, ovicola, ovicola-glabra, ovicoloides, pedunculata, pharetrata, pileata, pomiformis, rosaeformis, rugosa, sessilis, sloanei, strombylosa, thorntoni, thorntoninux, umbellata, urnalis, variabilis, urnalis-schraderi, cucurbita, dipsaciformis, excupula, fletcheri.
OPISTHOSCELIS conica, fibularis, globosa, maculata, mammularis, maskelli, nigra, pisiformis, serrata, spinosa, subrotunda, verrucula.
ASCELIS attenuata, echiniformis, praemollis, schraderi.
WARBURTONIA frenchi.
LECANIODIASPIS eucalypti, frenchi, convexus, newmani.
GOSSYPARIA confluens.
ERIOCOCCUS confusus, coriaceus, eucalypti, simplex, simplex-dealbata, tepperi, tricarinatus, serratilobis, crofti, apiomorphae, gregarius, irregularis, picta, tessellatus.
SPHAEROCOCCUS elevans, obscuratus, pustulans.
SPHAEROCOCOPSIS inflatipes.
OUROCOCCUS cobbii, eucalypti.
LACHNODIUS eucalypti, lectularius.
PSEUDOCOCCUS lobulatus.
TACHARDIA melaleucae.
LECANIUM oleae.
CTENOCHITON eucalypti.
CERONEMA caudata.
PULVINARIA maskelli.
CHIONASPIS assimilis, ethelae, eugeniae, formosa, eucalypti, frenchi, angusta.
ASPIDIOTUS extensus, perniciosus, camelliae, subrubescens, rossi, acaciae, eucalypti, alatus, confusus, rubribullata, subrubescens-corticoides, rossi-victoriae, fuscus, tasmaniae, miniatae, ficus, amplius, cyanophylli, articulatus, personatus.
MASKELLIA globosa.
LEPIDOSAPHES cordylinidis, grisea, lidgetti, bicornis, eucalypti, bicornis-alba.
FIORINIA lidgetti.
EUCHARIS (Amaryllidaceae).
ASTEROLECANIUM aureum.
HEMICHIONASPIS minor.
EUGENIA (Myrtaceae).
LLAVEIA primitiva-pimentae.
CAPULINIA jaboticabae, crateriformans.
ERIOIDES cuneiformis.
CARPOCHLOROIDES viridis.
STICTOLECANIUM ornatum.
LECANIUM tessellatum, jaboticabae, bicruciatum, psidii, mangiferae.
PULVINARIA eugeniae, psidii, grabhami.
CEROPLASTES fairmairii, formosus, rubens.
VINSONIA stellifera.

EUGENIA (Myrtaceae)—*cont.*
EDWALLIA rugosa.
CHIONASPIS eugeniae.
FIORINIA fioriniae.
ASPIDIOTUS fimbriatus, virescens, hederae, ficus, camelliae, destructor, personatus.
ODONASPIS pimentae.
LEPIDOSAPHES rubrovittatus, ungulata.
PARLATORIA oleae, proteus.

EUONYMUS (Celastraceae).
LECANIUM oleae, coryli, nigrofasciatum, capreae.
PULVINARIA camelicola, euonymi, innumerabilis, betulae, floccifera.
DIASPIS pentagona.
CHIONASPIS citri, euonymi, acuminata, salicis.
ASPIDIOTUS euonymi, perniciosus, aurantii, rossi, camelliae, dictyospermi, ficus, lataniae.
PARLATORIA theae-euonymi.

EUPATORIUM (Compositae).
ORTHEZIA insignis.
ASTEROLECANIUM fimbriatum.

EUPHORBIA (Euphorbiaceae).
PALAEOCOCCUS rosae.
ICERYA euphorbiae.
WALKERIANA euphorbiae.
ORTHEZIA urticae.
ASTEROLECANIUM fimbriatum.
PSEUDOCOCCUS virgatus, longispinus.
LECANIUM longulum.
CEROPLASTES euphorbiae.
CEROCOCCUS alluaudi.
DIASPIS conservans, barrancorum, antiquorum.
ASPIDIOTUS trilobitiformis-darutyi, ferox, magnus, euphorbiae, fissus, taorensis, lenticularis, biformis, hederae.
CRYPTASPIDIOTUS austroafricanus.
LEPIDOSAPHES ulmi.
PARLATORIA mangiferae.

EUPHRASIA (Scrophulariaceae).
ASTEROLECANIUM fimbriatum.

EURYA (Ternstroemiaceae).
LECANIUM ochnaceae.
PULVINARIA aurantii, psidii.

EURYA (Ternstroemiaceae)—*cont.*
ASPIDIOTUS duplex.
LEPIDOSAPHES euryae.

EURYCLES (Amaryllidaceae).
CHIONASPIS dilatata.

EUTERPE (Palmaceae).
DIASPIS boisduvallii.

EVODIA (Rutaceae).
CHIONASPIS acuminata.
DINASPIS permutans.

EXCOECARIA (Euphorbiaceae).
LECANIUM longulum.
CEROPLASTES excoecariae.

EXOCARPUS (Thymeliaceae).
CEROCOCCUS bryoides, bryoides-stellatus.
PSEUDOCOCCUS hibbertiae.
CEROPLASTODES melaleucae.
POLIASPIS exocarpi.
ASPIDIOTUS junctlobius.
LEPIDOSAPHES casuarinae, subspiculifera.

FABIANA (Solanaceae).
PULVINARIA argentina.
CEROPLASTES longiseta.
ASPIDIOTUS fabianae.

FAGONIA (Zygophyllaceae).
ASPIDIOTUS nigra, hederae.

FAGRAEA (Loganiaceae).
LECANIUM psidii.
DIASPIS fragraeae.

FAGUS (Corylaceae) 'Beech.'
COELOSTOMIDIA assimilis, pilosa.
PHENACOLEACHIA zealandica.
CEROCOCCUS fagi.
FAGISUGA triloba.
PLATYPYGA fagi.
ERIOCOCCUS fagicorticis, pallidus, raithbyi, aceris.
RHIZOCOCCUS intermedius, maculatus, pulchellus, totarae, cavellei.
CRYPTOCOCCUS fagi.
PSEUDOCOCCUS iceryoides, obtectus, aceris, newsteadi.
RIPERSIA fagi.
PULVINARIA innumerabilis, betulae.
INGLISIA fagi.
ASPIDIOTUS ancylus, forbesi, ostreiformis, perniciosus.
LEPIDOSAPHES ulmi.

FATSIA (Araliaceae).
Pulvinaria psidii.
Protopulvinaria japonica.
FERONIA (Rutaceae).
Anomalococcus cremastogastri.
FESTUCA (Gramineae).
Eriococcus festucae.
Ripersia festucae.
Trionymus californicus.
Eriopeltis festucae, lichtensteinii.
FICUS (Moraceae).
Aspidoproctus verrucosus.
Drosicha maskelli, lichenoides.
Monophlebus octocaudata.
Icerya aegyptiaca, maxima, purchasi, seychellarum.
Gueriniella serratulae.
Tachardia lacca, fici, longisetosa.
Asterolecanium pustulans.
Lecaniodiaspis africana.
Anomalococcus cremastogastri.
Eriococcus crispus, lagerstroemiae.
Pseudococcus ficus, longispinus, setosus, adonidum, citri, crotonis, virgatus, virgatus-madagascariensis.
Phenacoccus mangiferae.
Stictococcus formicarii.
Lecanium ficus, longulum, depressum, nigrella, plebeium, nigrum, ficinum, oleae, persicae, tessellatum, crassum, hesperidum, desolatum, hemisphaericum, formicarii, expansum, expansum-javanicum, ramakrishnae, carpenteri.
Hemilecanium imbricans.
Pulvinaria ficus, psidii, psidii-philippina, jacksoni, cupaniae.
Lichtensia lutea.
Ceroplastes floridensis, rubens, rusci, townsendi-percrassus, ficus, quadrilineatus, gowdeyi, coniformis, ceriferus, galeatus.
Diaspis gennadii.
Schizaspis lobata.
Chionaspis manni, fici.
Howardia biclavis.
Hemichionaspis aspidistrae, minor, fici, minima.
Leucaspis japonica.

FICUS (Moraceae)—*cont.*
Aspidiotus cyanophylli, cydoniae, camelliae, trilobitiformis, articulatus, ficus, aurantii, africanus, sylvatica, fossor, obsita, orientalis, dictyospermi, personatus, lataniae.
Aonidia planchonioides.
Gymnaspis ficus.
Lepidosaphes citricola, ficus, ficifolii, mexicana, minima, pinniformis, conchiformis, luzonica.
Ischnaspis filiformis.
FILICES 'Ferns.'
Tessarobelus guerinii.
Orthezia cheilanthi.
Eriococcus insignis.
Macrocerococcus superbus.
Pseudococcus longispinus.
Ripersia filicicola.
Lecanium tessellatum, hesperidum-alienum, cockerelli, filicum, hemisphaericum, mori, diversipes, oleae, longulum.
Pulvinaria mammeae, floccifera.
Ceroplastes rubens.
Ctenochiton depressus.
Alecanopsis filicum.
Chionaspis dilatata, dubia.
Hemichionaspis aspidistrae.
Poliaspis media.
Lepidosaphes phymatodidis, ocellata, desmidioides.
FILICIUM (Burseraceae).
Tachardia albizziae.
FLACOURTIA (Flacourtiaceae).
Pseudococcus longispinus.
Diaspis pentagona-flacourtiae.
Howardia biclavis.
Parlatoria cingala.
FOUQUIERIA (Tamaricaciae).
Lecaniodiaspis rufescens.
FRAGARIA (Rosaceae) 'Strawberry.'
Icerya genistae.
Orthezia insignis.
Diaspis rosae.
Aspidiotus perniciosus.
FRAXINUS (Oleaceae) 'Ash.'
Fonscolombia fraxini.
Phenacoccus aceris, pettiti.

FRAXINUS (Oleaceae)—*cont.*
LECANIUM cerasifex, fraxini, oleae, nigrofasciatum, corni, robiniae-subsimile.
PULVINARIA fraxini, betulae.
ERICERUS pela.
DIASPIS pentagona.
CHIONASPIS salicis.
ASPIDIOTUS ancylus, juglansregiae-albus, perniciosus, townsendi, vagabundus, pyri.
LEPIDOSAPHES ulmi.
PARLATORIA oleae, affinis.
FRENELLA (Coniferae).
ERIUM frenellae.
FREYCINETIA (Pandanaceae).
PSEUDOCOCCUS montanus.
FUCHSIA (Onagraceae).
PSEUDOCOCCUS citri, longispinus.
CEROPLASTES albolineatus.
ASPIDIOTUS camelliae.
LEPIDOSAPHES lactea.
FUMARIA (Papaveraceae).
MACROCEROCOCCUS superbus.
CEROPUTO superbus.
FUNTUMIA (Apocynaceae).
PULVINARIA psidii.
CEROPLASTES ceriferus.
CHIONASPIS funtumiae, lutea.
FURCRAEA (Amaryllidaceae).
LECANIUM hesperidum, depressum.
ASPIDIOTUS furcraeicola, hederae.

GAERTNERA (Loganiaceae).
FIORINIA scrobicularum.
GAHNIA (Cyperaceae).
LEPIDOSAPHES cordylinidis.
GALIUM (Rubiaceae).
ORTHEZIA urticae.
PSEUDOCOCCUS pulverarius.
ASPIDIOTUS niger.
GARCINIA (Guttiferae).
LECANIUM zonatum.
PULVINARIA psidii.
CEROPLASTES rubens.
VINSONIA stellifera.
ASPIDIOTUS greeni, dictyospermi, rossi, rossi-ferrandii.
FIORINIA frontecontracta.
PARLATORIA proteus.

GARDENIA (Rubiaceae).
DROSICHA maskelli.
ORTHEZIA insignis.
LECANIUM viride, hemisphaericum, hesperidum, oleae.
PROTOPULVINARIA longivalvata.
CEROPLASTES ceriferus.
HOWARDIA biclavis.
ASPIDIOTUS articulatus, hederae, tayabanus.
GARRYA (Cornaceae).
ASPIDIOTUS hederae.
GARUGA (Amyridaceae).
TACHARDIA lacca.
GAULTHERIA (Ericaceae).
HEMICHIONASPIS minor.
GAYLUSSACIA (Ericaceae).
ASPIDIOTUS perniciosus.
GEIJERA (Rutaceae).
FIORINIA geijerae.
ASPIDIOTUS hederae, rossi.
GELONIUM (Euphorbiaceae).
INGLISIA chelonioides.
CHIONASPIS varicosa.
FIORINIA proboscidaria, saprosmae-gelonii.
GELSEMIUM (Loganiaceae).
ASPIDIOTUS hederae.
GENIOSTOMA (Loganaceae).
CTENOCHITON elongatus.
GENISTA (Leguminosae).
ICERYA genistae.
ASTEROLECANIUM fimbriatum.
LECANIUM genistae.
DIASPIS pentagona.
CHIONASPIS salicis.
ASPIDIOTUS hederae, niger.
LEPIDOSAPHES ulmi.
GERANIUM (Geraniaceae).
ORTHEZIA urticae, cataphracta.
ASTEROLECANIUM fimbriatum, pustulans.
PSEUDOCOCCUS bechuanae.
DIASPIS pentagona.
GIGANTOCHLOA (Gramineae).
ASTEROLECANIUM bambusae.
ANTONINA bambusae.
ODONASPIS canaliculata.
GLAUX (Primulaceae).
ORTHEZIA urticae.

GLEDITSCHIA (Leguminosae).
Pseudococcus burnerae.
Lecanium cynobati, rugosum, oleae.
Diaspis pentagona.
Chionaspis ortholobis, gleditsiae, spinicola.
Aspidiotus forbesi, fernaldi, africanus, ostreaeformis.
GLOBULARIA (Globulariaceae).
Asterolecanium rehi, fimbriatum.
Cryptophyllaspis bornmulleri.
Aspidiotus labiatarum.
GLYCINA (Leguminosae).
Lecanium wistariae.
GLYCOSMIS (Rutaceae).
Vinsonia stellifera.
GNETUM (Gnetaceae).
Pseudoparlatoria cristata.
Cryptoparlatoria uberifera.
GOODENIA (Goodeniaceae).
Icerya aegyptiaca.
GOSSYPIUM (Malvaceae) 'Cotton.'
Cerococcus hibisci.
Pseudococcus citri, virgatus, perniciosus, filamentosus, corymbatus, longispinus.
Phenacoccus gossypii.
Lecanium nigrum.
Pulvinaria jacksoni, maxima.
Inglisia malvacearum.
Hemichionaspis minor, townsendi, aspidistrae-gossypii.
GOURLIEA (Leguminosae).
Pseudococcus percerosus.
GRAPTOPHYLLUM (Acanthaceae).
Pseudococcus virgatus.
Lecanium nigrum.
Ischnaspis filiformis.
'GRASSES' (Gramineae).
Monophlebus fulleri.
Walkeriana africana.
Icerya pilosa, purchasi.
Margarodes hamelii, newsteadi, peringueyi, ruber, papillosus, niger.
Orthezia cataphracta, graminis, martelli, urticae.
Newsteadia floccosa.
Macrocerococcus superbus.
Eriococcus graminis, greeni, insignis, kemptoni, quercus, nativus, ruber, tenuis, formicola, salinus, festucae, inermis.
Pseudococcus arecae, calceolariae, graminis, herbicola, hibernicus, neomexicanus-alkalinus, nubicola, poae, roseotinctus, salinus, segregatus, walkeri, calceolariae-minor, bantu, elongatus, natalensis, socialis, mallyi, caffra, flagrans, timberlakei, aridorum, citri, pulverarius, kandyensis.
Phenacoccus cholodkovskyi, graminicola, graminis.
Ceroputo calcitectus, volynicus, superbus.
Natalensia fulleri.
Ripersia festucae, halophila, montana, porterae, salmonacea, subterranea, tenuipes, tomlini, trichura, corynephori, sporoboli, libera, oryzae, smithii, occulta, globata.
Trionymus perrisii, nanus, californicus, violaceus, insularis.
Ripersiella kelloggi, maritima.
Geococcus radicum.
Micrococcus similis.
Antonina graminis, parrotti, purpurea, indica, phragmitis, natalensis, transvaalensis, maritima.
Lecanium anthurii, tenuivalvatum.
Lecanopsis brevicornis, longicornis, formicarum, butleri.
Luzulaspis luzulae.
Spermococcus fallax.
Exaeretopus caricis.
Eriopeltis festucae, lichtensteinii, brachypodii, coloradensis.
Parafairmairia bipartita, gracilis.
Aclerda californica, digitata, obscura, subterranea, signoreti.
Diaspis uncinati.
Epidiaspis subterranea.
Chionaspis herbae, natalensis, graminis, spartinae.
Hemichionaspis aspidistrae.
Aspidiotus bilobis, hederae, graminella, sacchari, marlatti, panici.
Odonaspis janeirensis, graminis, ruthae.
Lepidosaphes ampelodesmae.

GREVILLEA (Proteaceae).
- Walkeriana cinerea.
- Aspidoproctus maximus.
- Asterolecanium pustulans.
- Pseudococcus grevilleae, filamentosus, citrophilus.
- Erium globosum, newmani.
- Lecanium longulum, hemisphaericum-hibernaculorum.
- Hemichionaspis minor.
- Howardia biclavis.
- Aspidiotus hederae, camelliae.
- Lepidosaphes grevilleae.

GREWIA (Tiliaceae).
- Tachardia lacca.
- Erium newmani.
- Tylococcus formicarii.
- Lecanium oleae.
- Inglisia castilloae.
- Chionaspis vitis.
- Fiorinia tumida, secreta.
- Cryptophyllaspis occultus, occultus-elongatus.

GRINDELIA (Compositae).
- Palaeococcus townsendi.
- Lecanium assimile.

GRISELINIA (Cornaceae).
- Leucaspis gigas.

GRISLEA (Lythraceae).
- Aspidiotus moorei.

GROSSULARIA (Grossulariaceae).
- Lecanium armeniacum, coryli, cynobati, rehi, ribis, persicae.
- Pulvinaria occidentalis.
- Fiorinia grossulariae.
- Aspidiotus forbesi, perniciosus.

GUAIACUM (Zygophyllaceae).
- Palaeococcus rosae.
- Lecanium tessellatum.
- Ceroplastes floridensis.
- Aspidiotus aurantii.

GUAZUMA (Sterculiaceae).
- Tachardia rotundata.
- Eriococcus aurescens.
- Lecanium nigrum.
- Hemichionaspis minor.

GUETTARDA (Rubiaceae).
- Howardia biclavis.

GUTIERREZIA (Compositae).
- Palaeococcus townsendi.
- Orthezia nigrocincta.
- Tachardia glomerella.
- Eriococcus tinsleyi-cryptus.
- Pseudococcus gutierreziae, neomexicanus.
- Aspidiotus gutierreziae.

GYMNOSPORIA (Celastraceae).
- Lecanium gymnospori.
- Aspidiotus gymnosporiae, lauretorum.

GYNANDROPSIS (Capparidaceae).
- Chionaspis gynandropsidis.

HABROTHAMNUS (Solanaceae).
- Pseudococcus citri.

HAKEA (Proteaceae).
- Palaeococcus australis, rosae.
- Asterolecanium hakeae.
- Eriococcus hakeae.
- Lecanium depressum.
- Pulvinaria maskelli-viminariae.
- Australichtensia hakearum.
- Chionaspis eugeniae.
- Aspidiotus hakeae, comperei, acaciae-propinqua.
- Aonidia rotunda.
- Gymnaspis perpusilla.
- Parlatoria petrophilae.
- Lepidosaphes defecta-tincta.

HALOXYLON (Chenopodiaceae).
- Pulvinaria orientalis.

HAMELIA (Rubiaceae).
- Orthezia insignis.

HARPULLIA (Sapindaceae).
- Tachardia albizziae.

HAROGANA (Guttiferae).
- Stictococcus gowdeyi.
- Inglisia conchiformis.

HEBERDENIA (Myrsinaceae).
- Aspidiotus lauretorum.

HEDERA (Araliaceae) 'Ivy.'
- Icerya purchasi.
- Orthezia urticae.
- Asterolecanium hederae, fimbriatum.
- Pseudococcus citri.
- Phenacoccus hederae, aceris.
- Lecanium hesperidum, maculatum.
- Filippia oleae.
- Lichtensia viburni.

HEDERA (Araliaceae)—*cont.*
Diaspis bromeliae.
Aspidiotus cydoniae-crawi, hederae, lauretorum, camelliae, ficus, dictyospermi, britannicus.
HEDYCARPUS (Euphorbiaceae).
Leucaspis stricta.
HEDYCARYA (Monimiaceae).
Ctenochiton viridis.
HEDYOTIS (Rubiaceae).
Chionaspis hedyotidis, galliformens.
HELIANTHEMUM (Cistaceae).
Newsteadia floccosa.
Asterolecanium fimbriatum.
Lecaniodiaspis sardoa.
Cerococcus eremobius.
Lepidosaphes ulmi.
HELIANTHUS (Compositae).
Phenacoccus helianthi.
Aspidiotus helianthi.
HELICHRYSUM (Compositae).
Cerococcus bryoides.
Eriococcus sordidus.
Lecanium oleae.
Aspidiotus niger.
HELICONIA (Musaceae).
Diaspis boisduvallii.
Hemichionaspis aspidistrae.
HELICTERES (Sterculiaceae).
Cerococcus indicus.
Eriococcus paradoxus-indicus.
HELIOTROPIUM (Boragineae).
Diaspis pentagona.
Chionaspis major.
HEMICYCLEA (Euphorbiaceae).
Tachardia albizziae.
Lecanium expansum.
Aonidia echinata.
HERACLEUM (Compositae).
Orthezia urticae.
HERNIARIA (Caryophyllaceae).
Margarodes polonicus.
HETERODENDRON (Sapindaceae).
Tachardia melaleucae.
Aspidiotus hederae.
HEVEA (Euphorbiaceae).
Asterolecanium pustulans-seychellarum.
Pseudococcus virgatus.
Lecanium nigrum.
Vinsonia stellifera.
Chinoaspis dilatata.
Hemichionaspis aspidistrae.
Aspidiotus cyanophylli, destructor, transparens, ficus, personatus.
Parlatoria proteus.
Lepidosaphes rubrovittatus.
HIBBERTIA (Dilleniaceae).
Pseudococcus hibbertiae.
HIBISCUS (Malvaceae).
Conchaspis angraeci-hibisci.
Asterolecanium pustulans.
Cerococcus hibisci.
Pseudococcus bromeliae, cocotis, filamentosus.
Lecanium hesperidum, depressum, nigrum.
Pulvinaria cestri, citricola.
Ericerus pela.
Ceroplastes ceriferus, dugesii, ficus.
Inglisia malvacearum.
Stictococcus diversiseta.
Diaspis bromeliae, pentagona.
Howardia biclavis.
Hemichionaspis minor, mussaendae, aspidistrae.
Aspidiotus longispinus, perniciosus, cydoniae.
Parlatoria chinensis.
HIERACEUM (Compositae).
Margarodes polonicus.
Orthezia urticae.
Asterolecanium fimbriatum.
Ceroputo pilosellae.
HIPPEASTRUM (Amaryllidaceae).
Pseudococcus citri.
HIPPOCREPIS (Leguminosae).
Asterolecanium fimbriatum.
HIPPOPHAES (Elaeagnaceae).
Phenacoccus aceris.
Chionaspis salicis.
Lepidosaphes ulmi.
HIPTAGE (Malpighiaceae).
Lecanium tessellatum, viride.
HOHERIA (Malvaceae).
Eriococcus hoheriae.
Chionaspis dysoxyli.
Leucaspis stricti.
HOLACANTHA (Simarubaceae).
Diaspis toumeyi.

HOMALOMENA (Araceae).
PINNASPIS buxi.
HOMOGYNE (Compositae).
ORTHEZIA cataphracta.
HORDEUM (Gramineae).
PSEUDOCOCCUS hordei.
HOSTA (Liliaceae).
HEMICHIONASPIS aspidistrae.
HOWEA (Palmaceae).
LECANIUM tessellatum.
FIORINIA kewensis.
HOYA (Asclepiadaceae).
PSEUDOCOCCUS hoyae.
HUMBOLDTIA (Leguminosae).
LACHNODIUS humboldtiae.
HUMULUS (Urticaceae) 'Hop.'
ORTHEZIA urticae.
PHENACOCCUS aceris.
HURA (Euphorbiaceae).
LECANIUM oleae, hurae.
CEROPLASTES cirripediformis.
HYALIS (Compositae).
PSEUDOCOCCUS mendozinus.
HYDRANGEA (Saxifragaceae).
LECANIUM persicae, magnoliarum-hortensiae.
HYGROPHILA (Acanthaceae).
PSEUDOCOCCUS viridis.
LECANIUM nigrum, oleae.
PULVINARIA obscura.
HYMENAEA (Leguminosae).
LICHTENSIA zapotlana-townsendi.
HOWARDIA biclavis.
HYMENANTHERA (Violaceae).
PULVINARIA maskelli-novemarticulata.
CTENOCHITON hymenantherae.
LEPIDOSAPHES hymenantherae.
HYMENOCLEA (Compositae).
ORTHEZIA sonorensis.
PSEUDOCOCCUS hymenocleae.
HYPERICUM (Guttiferae).
ASTEROLECANIUM fimbriatum.
LECANIUM pulchrum.
ASPIDIOTUS privignus, camelliae, labiatarum.
HYPHAENA (Palmaceae).
CHIONASPIS pseudonivea.
ASPIDIOTUS fissidens-constricta.
HYPOCALYMMA (Myrtaceae).
TACHARDIA convexa.
SPHAEROCOCCUS pulchellus.
HYPTIS (Labiatae).
DIASPIS pentagona.
HYSSOPUS (Labiatae).
ASPIDIOTUS rossi.

IDESIA (Flacourtiaceae).
PULVINARIA idesiae.
ILEX (Aquifoliaceae) 'Holly.'
PALAEOCOCCUS pulcher.
LECANIUM hesperidum, notatum, nigrofasciatum, oleae.
CERONEMA japonica.
CEROPLASTES floridensis, grandis, rubens, rusci.
DIASPIS penzigi.
PINNASPIS javanica.
ASPIDIOTUS britannicus, hederae, camelliae, ficus, perseae, lauretorum, paeoniae, dictyospermi.
PARLATORIA theae-viridis.
ILLIGERA (Combretaceae).
ASPIDIOTUS replicatus.
IMPATIENS (Geraniaceae).
CEROPLASTES floridensis.
INDIGOFERA (Leguminosae).
HEMICHIONASPIS chionaspiformis, minor.
INGA (Leguminosae).
ICERYA montserratensis.
TACHARDIA ingae.
ASTEROLECANIUM pustulans.
CEROPLASTES confluens.
IPOMOEA (Convolvulaceae).
ORTHEZIA insignis.
PSEUDOCOCCUS citri.
LECANIUM hesperidum, batatae.
PULVINARIA urbicola.
CEROPLASTODES cajani.
CEROPLASTES cirripediformis.
HEMICHIONASPIS minor.
ASPIDIOTUS cyanophylli, excisus.
IRIS (Iridaceae).
ASPIDIOTUS dictyospermi.
IXORA (Rubiaceae).
LECANIUM mangiferae, hemisphaericum, maritimum, hesperidum, viride.
PULVINARIA ixorae.

IXORA (Rubiaceae)—*cont.*
ASPIDIOTUS trilobitiformis, articulatus.
LEPIDOSAPHES ixorae.
ISCHNASPIS filiformis.

JABOTICABA (Myrtaceae).
ASPIDIOTUS trilobitiformis.
JASMINUM (Oleaceae).
ICERYA purchasi.
ASTEROLECANIUM pustulans.
PHENACOCCUS ornatus.
LECANIUM hesperidum, mangiferae, acuminatum.
DIASPIS pentagona.
CHIONASPIS euonymi.
HOWARDIA biclavis.
ASPIDIOTUS lataniae, forbesi, personatus, dictyospermi, aurantii, rossi, hederae, trilobitiformis, britannicus.
PARLATORIA blanchardi.
ISCHNASPIS filiformis.
JATROPHA (Euphorbiaceae).
LLAVEIA axin.
PSEUDOCOCCUS virgatus.
LECANIUM nigrum.
HEMILECANIUM imbricans.
HEMICHIONASPIS minor.
JOSSINIA (Myrtaceae).
PULVINARIA grabhami.
JUGLANS (Juglandaceae) 'Walnut.'
PSEUDOCOCCUS bakeri, citrophilus.
LECANIUM cockerelli, juglandifex, juglandis, oleae, coryli.
PULVINARIA betulae.
DIASPIS pentagona.
CHIONASPIS furfura, ortholobis.
EPIDIASPIS lepèri.
ASPIDIOTUS aesculi-solus, forbesi, juglandis, juglans-regiae, perniciosus, ulmi.
LEPIDOSAPHES juglandis, ulmi, multipora, conchiformis.

JUNIPERUS (Coniferae).
ERIOCOCCUS gillettei.
PSEUDOCOCCUS juniperi, vovae.
DIASPIS juniperi, carueli, atlantica, visci.
CHIONASPIS striata.
AONIDIA juniperi.
CRYPTOPARLATORIA leucaspis.
ASPIDIOTUS maderensis.
CRYPTASPIDIOTUS mediterraneus.
FIORINIA juniperi.
LEPIDOSAPHES juniperi.
JUSTICIA (Acanthaceae).
ORTHEZIA insignis.
LECANIUM hemisphaericum, nigrum, viride.
CHIONASPIS longispina.

KENNEDYA (Leguminosae).
ICERYA purchasi.
ASPIDIOTUS kennedyae.
KENTIA (Palmaceae).
PSEUDOCOCCUS pseudonipae, nipae.
DIASPIS boisduvallii.
FIORINIA pellucida.
ASPIDIOTUS hederae, dictyospermi, ficus.
PARLATORIA proteus.
KHAYA (Meliaceae).
DIASPIS senegalensis.
KIBARA (Monimiaceae).
MYXOLECANIUM kibarae.
KIGELIA (Bignoniaceae).
ASPIDIOTUS lataniae.
KNIGHTIA (Proteaceae).
ERIOCOCCUS multispinus.
KOELREUTERIA (Sapindaceae).
PULVINARIA horii.
KRAUNHIA (Leguminosae).
LECANIUM corni, persicae.
KUNZEA (Myrtaceae).
ERIOCOCCUS leptospermi, araucariaminor.
KYDIA (Malvaceae).
TACHARDIA lacca.

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